EVALUATION OF UDDER CONFORMATION, WEIGHT, BODY CONDITION, REPRODUCTION, DISPOSITION, AND CALF GROWTH, IN *BOS INDICUS*-*BOS TAURUS* COWS

A Dissertation

by

AARON JAY COOPER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2011

Major Subject: Animal Breeding

Evaluation of Udder Conformation, Weight, Body Condition, Reproduction, Disposition,

and Calf Growth in *Bos indicus – Bos taurus* Cows

EVALUATION OF UDDER CONFORMATION, WEIGHT, BODY CONDITION, REPRODUCTION, DISPOSITION, AND CALF GROWTH, IN *BOS INDICUS*-*BOS TAURUS* COWS

A Dissertation

by

AARON JAY COOPER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Chair of Committee,	James O. Sanders
Committee Members,	David G. Riley
	Andy D. Herring
	Clare A. Gill
	Jason E. Sawyer
Head of Department,	H. Russell Cross

August 2011

Major Subject: Animal Breeding

ABSTRACT

Evaluation of Udder Conformation, Weight, Body Condition, Reproduction, Disposition, and Calf Growth in *Bos indicus – Bos taurus* Cows. (August 2011)

Aaron Jay Cooper, B.S., Texas A&M University; M.S., University of Nebraska-Lincoln

Chair of Advisory Committee: Dr. James O. Sanders

Data were analyzed on 2 to 6 yr old cows to evaluate sire and family effects. Cows were produced in the McGregor Genomics Project from 13 embryo transfer (ET) full sib families (n = 188, F_2 Nellore-Angus (NA)) and 4 half sib natural service (NS) families (n = 114, out of 1/2 Brahman 1/2 British dams) from the same 4 F_1 NA sires. The ET and NS cows were analyzed separately and together as paternal half sibs (PHS). Daughters of bull 437J had the highest calving rate and weaning rate; daughters of 551G were the lowest in ET, and daughters of 297J were the lowest in NS. Calves out of daughters of 551G were the heaviest at birth; those from of daughters of 437J were the lightest in NS and PHS. Calves out of daughters of 297J were the heaviest at weaning in ET and PHS, and those from daughters of 432H were the lightest. Calves from daughters of 297J and 437J gained the most weight and those from daughters of 432H gained the least. Daughters of 297J and 551G had longer and larger diameter teats and lower udder support scores (more pendulous) than daughters of 432H and 437J. Daughters of 437J had the highest body condition score (BCS); daughters of 551G were the lowest in ET and NS. Calves from daughters of 297J had the highest BCS at weaning. Those out of

daughters of 551G had the lightest WWT, those out of daughters of 437J were the heaviest in NS and PHS, and those out of daughters of 432H were the heaviest in ET. Daughters of 437J and 551G scored the highest for disposition (least docile) in ET and PHS, and daughters of 432H were lowest. The regression of WWT on weaning age was 0.82 ± 0.07 in ET, 0.71 ± 0.08 in NS, and 0.78 ± 0.05 kg/d in PHS. There appears to be sufficient variation within and between these full sib and half sib families for use in QTL analysis for major genes affecting cow productivity in NA crosses.

DEDICATION

This is dedicated my dad, Steven Charles Cooper, and my son, Cain Mason Cooper

ACKNOWLEDGEMENTS

There are so many people to acknowledge who have provided me assistance and support in numerous ways. First and foremost, I thank God. Without God this dissertation would not exist. The journey and path He has led me down bought much joy and also adversity along the way. I am thankful for that and the outcome He blessed me with. My wife Ashlei has always been there for me and sacrificed a lot for me to be able to complete my final degree. For that I am thankful. Dr. Sanders has helped me inside and outside of the classroom more than any other professor in my academic career. He is always willing to provide assistance for whatever I need. He is a good man and a friend. I am thankful that I had a great committee in Drs. Riley, Herring, Gill, and Sawyer. They were always willing to help and provided great knowledge in the field of animal breeding. Finally, to all of my friends and family, I say thank you for the important role you have all played in helping me complete this degree.

TABLE OF CONTENTS

		Page
ABSTRACT		iii
DEDICATION		v
ACKNOWLEDGEMENTS		vi
TABLE OF CONTENTS		vii
LIST OF TABLES		ix
CHAPTER		
I	INTRODUCTION	1
II	LITERATURE REVIEW	3
	Bos indicus – Bos taurus Cow Performance	3
	Cow Size and Body Condition	5
	Udder Traits	7
	Disposition	14
	Calf Growth	16
III	METHODS AND MATERIALS	18
	Statistical Analysis	20
IV	RESULTS AND DISCUSSION	23
	Calving Rate	28
	Weaning Rate	39
	Disposition	43
	Average Teat Length	45
	Average Teat Diameter	50
	Udder Support Score	51
	Birth Weight	52
	Weaning Weight	57
	Preweaning Average Daily Gain	63
	Cow Body Condition Score	65

CHAPTER		Page
	Calf Body Condition Score	67
	Cow Weight	72
	Correlations	74
V	SUMMARY	80
LITERATURE CITED		86
VITA		91

LIST OF TABLES

TABLE		Page
1	Number of calves born by calving year, sire of cow, and family	23
2	Number of calves born by parity, sex of calf, and type of dam	24
3	Simple means for traits measured among full sibling (embryo transfer) families	25
4	Simple means for traits measured among half sibling (natural service) families	25
5	Simple means for traits measured among all cows combined (paternal half siblings)	26
6	Simple means of full sibling (embryo transfer) cows by sire of cow	27
7	Simple means of full sibling (embryo transfer) cows by family	27
8	*P*-values and residual variance estimates for traits among full sibling (embryo transfer) cow families	29
9	*P*-values and residual variance estimates for traits from half sibling (natural service) cow families	31
10	*P*-values and residual variance estimates for traits from all cows combined (paternal half siblings)	33
11	Least squares means and standard errors of calving rate, weaning rate, and disposition among full sibling (embryo transfer) cow families for sire of cow, family, cow age, and season of cow birth effects	35

TABLE Page

12 Least squares means and standard errors of calving and weaning rate and disposition among half sibling (natural service) cows for sire and age of cow effects 37

13 Least squares means and standard errors of calving and weaning rate and disposition among all cows combined (paternal half sibling) for sire of cow, cow age, and season of cow birth effects 40

14 Least squares means and standard errors of teat length and diameter and udder support scores among full sibling (embryo transfer) cow families for sire of cow, family, cow age, and season of cow birth effects 46

15 Least squares means and standard errors of teat length and diameter and udder support scores among half sibling (natural service) cows for sire and age of cow effects 48

16 Least squares means and standard errors of teat length and diameter and udder support scores among all cows combined (paternal half sibling) for sire of cow, cow age, and season of cow birth effects 49

17 Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among full sibling (embryo transfer) cow families for sire of cow, family, cow age, season of cow birth, and sex of calf effects 53

TABLE Page

18 Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among half sibling (natural service) cows for sire of cow, cow age, and sex of calf effects 56

19 Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among all cows combined (paternal half siblings) for sire of cow, cow age, and sex of calf effects 58

20 Least squares means and standard errors of cow body condition score, calf body condition score, and cow weight among full sibling (embryo transfer) cow families for sire of cow, family, cow age, season of cow birth, sex of calf, calving record, and lactation status effects 68

21 Least squares means and standard errors of cow body condition score, calf body condition score and cow weight among half sibling (natural service) cows for sire of cow, cow age, sex of calf, calving record, and lactation status effects 70

22 Least squares means and standard errors of cow body condition score, calf body condition score, and cow weight among all cows combined (paternal half sibling) for sire of cow, cow age, sex of calf, calving record, and lactation status effects 71

23 Pearson correlation coefficients and *P*-values among traits measured in full sibling (embryo transfer) cow families 75

TABLE Page

24 Pearson correlation coefficients and *P*-values among traits measured in half sibling (natural service) cow families... 76

25 Pearson correlation coefficients and *P*-values among traits measured in all cows combined (paternal half siblings) 77

CHAPTER I

INTRODUCTION

Udder conformation and milking ability are essential characteristics for calf survival, growth, and cow longevity. Although very little udder conformation data from within lines or among families have been reported, there seems to be a tendency for some *Bos indicus* influenced cows to have udder and teat problems (Cartwright, 1980) and it can affect a calf's ability to nurse (Wythe, 1970). There is evidence of genetic differences for milk production within breeds (Montaño-Bermudez and Nielsen, 1990) with heritability reported as moderate (Fuerst-Waltl et al., 1998). Beef cows in many breeds are expected to be at peak calf production from the ages of 5 to 10 years. However, even if a cow produces acceptable quantities of milk but has poor udder and teat conformation, then she may not be able to stay in the herd long.

Nutritive requirements of cows represent as much as 65% of production costs. Higher milk production potential translates into increased maintenance requirements of the cow, even when not lactating (Ferrell and Jenkins, 1985). Body condition scores are used to visually estimate energy reserves of the cow (Herd and Sprott, 1986) and are correlated with several reproductive traits that greatly affect net income (Kunkle et al., 1994). Improvements in reproductive performance, usually measured as CR and WR, can be up to 4-fold more important than improvements in end product traits in a conventional cow-calf operation selling market calves at weaning (Melton, 1995). Improvement in reproductive efficiency has generally been slow because of low

---

This dissertation follows the style of Journal of Animal Science.

heritability, the binomial nature of fertility data from a short-controlled breeding season, or late expression of traits in the life of the animal (MacNeil and Mott, 2006). Increased WR represents the greatest time-adjusted economic value to commercial cow-calf producers, simply because without a calf to sell no other characteristic has much meaning (Melton, 1995). It is economically essential to have cows that get pregnant, carry the pregnancy to full term, have a live calf, and then raise that calf to weaning. It is just as important that the cow breed back after parturition while raising a calf. It is an appropriate goal of the producer to have cows that raise a calf once a year, every year, for many years.

Cow disposition (temperament) is a factor that influences the value of the cow to producers. Cows with more aggressive or flighty dispositions are more difficult to handle and could possibly injure handlers. It is not well understood how sire, dam and/or recipient affects cow disposition at calving nor have associations to other cow production traits been thoroughly evaluated.

Calf growth characteristics such as BWT, WWT and PW ADG are important to producers. Low BWT is desirable to reduce or avoid dystocia. In order to have desirable BWT and WWT there has to be a relatively high amount of PW ADG. Preweaning growth has both direct and maternal components (Meyer et al., 1994).

Objectives of this project were to: (1) investigate differences in udder conformation characteristics, weight, body condition, reproduction, disposition, and calf size and growth within and across families, and (2) evaluate associations among udder, reproduction, disposition, and calf growth traits.

CHAPTER II

LITERATURE REVIEW

Bos indicus - Bos taurus *Cow Performance*

Cartwright et al. (1964) documented the excellent reproductive and maternal performance of the Brahman x British cross cow. Sanders (1980) discussed the history and characteristics of several *Bos indicus* breeds of cattle including Nellore. Nellore (also known as Ongole) originated from India. This breed of cattle is important in the cattle industry of Brazil and one of the most numerous breeds of cattle in the world. The author stated that the Nellore, Guzerat, and Gir have had the most influence on Zebu cattle breeding in the United States.

Cundiff (2005) reported data for 8,484 calves produced in Cycle IV (1986-1990), Cycle V (1992-1994), and Cycle VIII (2001-2002) of the Germplasm Evaluation Program at the U.S. Meat Animal Research Center in Clay Center, Nebraska. Tropically adapted breeds compared were Nellore, Longhorn, Brahman, Boran, Tuli, Beefmaster, Brangus, Bonsmara, and Romosinuano for growth and reproductive traits of F_1 cross females producing their first calves at 2 yr of age. The dams of the F_1 cows were Hereford, Angus, or MARC III, depending on the particular cycle. The F_1 Brahman-sired females ranked lowest for CR (0.74) and WR (0.65) as 2 yr olds. Females from Nellore sires had a CR of 0.90 and a WR of 0.73 as 2 yr olds. Females from Brangus sires had a CR of 0.90 and the females from Beefmaster sires had 0.96 as 2 yr olds. Weaning rate from Brangus sired females was 0.87 and from Beefmaster sired females was 0.89 as 2 yr olds. Birth weights were heavier ($P < 0.05$) for progeny of Hereford- and Angus-sired F_1

females than those by other breeds and Nellore-, Brahman-, and Longhorn-sired females required less assistance at calving than those by other breeds. Calves from 2 yr old Brahman- and Nellore-sired females were the heaviest at 205 days (215.0 and 214.1 kg, respectively); however, for 205 day WWT per cow exposed, calves out of 2 yr old Brahman-sired females ranked the lowest (140 kg) and calves out of Beefmaster-sired females ranked the highest (185.9 kg). As 3 to 7 yr old cows, the reproductive performance of the Brahman-sired cows was considerably higher and the 205 day WWT per cow exposed was highest for the Brahman-sired cows (201.8 kg).

Sanders et al. (2005) evaluated cow reproduction and maternal traits in Brahman (B), Angus (A), Nellore (N), Hereford (H), and crosses involving those breeds for heterosis and heterosis retention. The comparison herds were made up of a minimum of 50 cows in each of 14 different groups (4 purebred, 3 F_1, 2 F_2, 2 first generation groups of 3/8 *Bos indicus*/ 5/8 British breeding, 2 second generation 3/8 *Bos indicus*/ 5/8 British breeding, and 1 four-breed crossbred group). The following least squares means includes pooled estimates of all combinations and reciprocal types within each breed group presented in this study. Calving rate for F_1 BA, F_1 BH, F_2 BA, and F_2 BH were 0.90, 0.89, 0.74, and 0.87, respectively. Weaning rate for F_1 BA, F_1 BH, F_2 BA, and F_2 BH were 0.82, 0.82, 0.64, and 0.81, respectively. Weaning weights for calves out of F_1 BA, F_1 BH, F_2 BA, and F_2 BH cows were 220.7, 232.6, 208.2, and 211.6, respectively. For 4 yr old cows, the least squares means for cow weight (CW) for F_1 BA, F_1 BH, F_2 BA, F_2 BH were 533.4, 523.2, 493.0, and 532.6 kg, respectively.

Bailey et al. (1988) evaluated reproductive traits and preweaning growth of progeny from young H, Red Poll (R), HR, RH, AH, A x Charolais (C), BH, and BA cows. First-calf heifers were mated with Red Angus bulls and Santa Gertrudis sires were used for each cow's second and third breeding seasons. For pregnancy rate, BH and BA dams were the highest (0.96 and 0.94, respectively). For CR similar results occurred with BH and BA ranking the highest at 0.91. Weaning rate for BH and BA were 0.88 and 0.82, respectively. At birth, BH and BA dams had the lightest claves with averages of 33.5 and 30.8 kg, respectively. Averages of WWT for calves out of BH and BA cows were 213.6 and 204.2 kg, respectively.

Cow Size and Body Condition

Olson et al. (1982) analyzed the effects of cow size on cow reproduction and productivity (adjusted weaning weight/cow exposed) and calf performance in H cows. Cows were divided into 4 groups based on weight. Cow weight and wither height were collected during the summer following the breeding season for the second calf. The authors stated nutrition was not a limiting factor in this experiment. Least squares means for CW for the 4 groups were 450.9, 517.1, 566.8, 646.9 kg for small, medium, large, and very large, respectively. Compared to the herd average, small, medium, large, and very large cows weaned -1.5, +3.6, +11.2, and -6.7% weight of calf/cow exposed, respectively. Birth weight, preweaning gain, and adjusted WWT were significantly greater ($P < 0.001$) for calves out of medium and large cows than small and very large cows.

Vargas et al. (1999) evaluated frame size (FS) and BCS on performance in Brahman cows. Calving rate in large FS second-parity dams was 27% less ($P < 0.05$) than in small and medium FS dams. In third or greater-parity dams, CR was greater ($P < 0.05$) for small FS cows than for medium and large FS cows. Across the first through third parity groups, CR improved with increasing BCS. Weaning rates of large FS first- and second-parity dams were less ($P < 0.05$) than those of small and medium FS dams. Second-parity dams with BCS 3 had lower ($P < 0.05$) WR than dams with BCS 4 and 5. Within first- and third or greater-parity dams, BWT of calves born to small FS cows were the lightest, and those born to large FS dams were the heaviest; those born to medium FS dams were intermediate ($P < 0.05$). In second-parity dams, BWT of calves of large FS dams were greater ($P < 0.05$) than those of small and medium FS dams. Small FS cows had calves with lower ($P < 0.05$) WWT than those weaned by higher FS cows. In the third or greater-parity group, large FS cows weaned heavier calves ($P < 0.05$) than other cows. In all parity groups, calves out of large FS cows had greater ADG ($P < 0.05$) than those from small and medium FS cows. Small and medium FS females had more kilograms of calf produced per cow exposed than large FS females.

Variation in BCS of cows has a number of practical implications. Herd and Sprott (1986) stated the condition of cows at calving is associated with length of post partum interval, subsequent lactation performance, health and vigor of the newborn calf and the incidence of calving difficulties in extremely fat heifers. The condition of cows at breeding affects their reproductive performance in terms of services for conception, calving interval and percentage of open cows.

Udder Traits

Dairy and beef cows are selected for different traits. However, udder characteristics from dairy cows can be used as a means of comparison in beef cattle. Fuerst-Waltl et al. (1998) evaluated genetic relationships between 305 d milk yield and 17 type traits in first-lactation Holsteins utilizing 24,470 dam-daughter records. Estimates of heritabilities were reported for milk yield (0.34 ± 0.009 and 0.36 ± 0.004), teat length (0.23 and 0.25) and udder depth (0.25 and 0.31) by offspring-parent regression and paternal half sibling analysis, respectively. The authors did not report SE on individual type trait heritabilities, but stated the SE ranged from 0.009 to 0.01 with offspring-parent regression and 0.003 to 0.006 with half sibling analysis.

Riley et al. (2001a, b) evaluated F_1 cows sired by Angus, Gray Brahman, Gir, Indu-Brazil, Nellore, and Red Brahman bulls from Hereford dams in central Texas. The Nellore-sired cows had smaller ($P < 0.05$) postpartum teat length than all other crossbred groups and smaller ($P < 0.10$) postpartum teat diameter and higher ($P < 0.10$) udder support scores (less pendulous udders) than Gir, Indu-Brazil, and Red Brahman crossbreds. Nellore crossbred cows had the highest percentage (60%) of cows remaining in the herd at the end of the 15 year study. The authors concluded that this could have been due at least in part to overall better condition of their udders. Of the 116 cows evaluated, 22.4% were removed because of udder problems; this being the second largest reason for culling in the study behind reproductive failure (failing to wean a calf for the second time). Udder culling factors included structural problems, such as excessively large teats or injured or diseased udders, inadequate milk production or combinations of these factors.

Rohrer et al. (1988) analyzed productive longevity, mean life span, and reasons for removal from the herd in 498 cows of 15 breed-types in Texas. The 498 cows were produced in a five-breed diallel (reciprocals pooled together) involving Angus, Brahman, Hereford, Holstein, and Jersey. Cows were removed from this study based on 10 categories: reproductive failure, calving difficulty, experimental culling (cow culled after completing a 2 yr nutrition experiment), mammary problems, structurally unsound, severe prolapse, general illness, cancer eye, nutritional abnormalities, and unknown causes. In this study, mammary-related problems were defined as removal due to severe mastitis or a nonfunctional udder. No cows were culled based on teat shape alone, and neonatal calves from cows with large, pendulous udders received assistance for a few days to promote nursing. Cows culled due to mammary problems accounted for 9.6% of the cows in the study. Mammary problems began to become important reasons for removal at around 5 yr of age and continued to have increasing importance as age increased.

Rogers and Hargrove (1993) reported Holsteins with shorter teats were associated with lower somatic cell milk counts than long teats, and ostensibly less incidence of mastitis. Cows with shorter teats are thought to produce lower amounts of milk (Sapp et al., 2004). However, Freeman (1976) reported Holstein cows with shorter teats produced more milk than cows with long teats.

Cartwright (1980) stated Brahman cattle are known to have more malformed teats and udders than other beef breeds. Frisch (1982) analyzed the effect of bottle teats on calf pre-weaning growth and weaning weight in Queensland, Australia. Measurements were taken on 892 cows for teat length and diameter within 2 d of calving from 8 different breeding lines. Lines of cattle used were grade Brahman and Africander, F_4 and greater generations of Hereford x Shorthorn (HS), Brahman x HS (BX) and Africander x HS (AX), and F_1 and F_2 generations of AX x BX. The grade Brahman and Africander cows were from ¾ to purebred *Bos indicus*. In addition, data were collected from commercial lines of Herefords and F_1 Sahiwal x Hereford. Teats with a diameter greater than or equal to 35 mm were classified as bottle teats. Frisch (1982) found that calves born to cows with 4 bottle teats had much higher mortality rates between calving and 2 mo of age ($P < 0.001$). Also, cows with 4 bottle teats had calves that were significantly lighter 2 d after birth ($P < 0.01$). However, cows with no bottle teats had the lightest calves at weaning ($P < 0.01$), and calves out of cows with 4 bottle teats were the heaviest at weaning (corrected for line differences in occurrence of “bottle” teats). This is assumed to be because cows with bottle teats had higher milk production. Among lines, the F_1 Sahiwal x Hereford and F_4 and later generations of Brahman x Hereford/Shorthorn had the highest proportion of bottle teats and also had the highest mortality rates up to 2 mo of age. It is also important to note that the 7 cows in this study that had both 4 bottle teats and pendulous udders had calves that were not able to nurse and that were dead within a few days of birth. It was decided that teat diameter was a more important factor than teat length in the ability of the calf to nurse. However, an optimum range for teat length was established. Calves from cows with all 4 teats less than or equal to 50 mm long averaged 139 kg at weaning, which was 5 kg less ($P < 0.05$) than those from cows with at least one teat being longer than 50 mm (corrected for line differences in teat length). Cows with at least one teat longer than 90 mm had a calf mortality rate of 0.23, which was significantly higher than that for calves born to cows with 4 teats shorter than 90 mm (0.078).

Studies of dairy cows (Moore et al., 1981; Seykora and McDaniel, 1986) have frequently reported that larger teat diameter is associated with increased milk production. However, large teat diameter has been associated with increased mastitis in dairy cows (Hickman, 1964; Seykora and McDaniel, 1986). In beef cattle, if the calf cannot nurse because of large teat diameter, especially in the critical first hours following birth, increased milk production is of little value. Edwards (1982) noted that the udder conformation of the dam was the most important factor determining the time to first suckling in dairy calves. Wythe (1970) concluded smaller teats were associated with improved calf nursing ability in a study of Brahman cattle in Texas. Riley et al. (2001a, b) stated there may be no realized benefit of increased milk yield in range conditions if it is difficult for a calf to nurse for any reason. The combination of a pendulous udder with large teat length or teat diameter challenges the nursing ability of most, if not all, calves.

Riley et al. (2004) stated that possibly the structure and quality of the dam’s udder was one of the most important age-dependant factors affecting calf mortality. Notes were taken associated with calving records, and in 41 of the 392 calf deaths and in 46 of the 378 calves with poor vigor, the cows had been reported as having poor udders or teats.

Wythe (1970) stated any deviation from correct teats and udder results in a sharp decrease in nursing ability.

Short et al. (1991), using Holstein cows, reported high genetic correlations between teat length and other udder size traits: longer teats were associated with weaker udder support and deeper udders. Riley et al. (2001a, b) stated this seems to be a problem in cow-calf beef production when calves must reach down to nurse. Short teats and less pendulous udders are easier for calves to reach and usually are easier to nurse. Ventorp and Michanek (1992) evaluated the importance of udder and teat conformation on teat-seeking behavior in newborn calves in 42 Swedish Holstein cow-calf pairs; 14 were first-calf heifers, 14 with their second calf, and 14 had calved for at least the third time. Height of the udder from the floor significantly ($P < 0.001$) affected the length of time from birth to first suckle. This suggested lower height was associated with more time before suckling. Calves from cow with “low slung” or more pendulous udders cannot be expected to obtain colostrum soon enough by natural suckling. The effect of parity on time of the first suckle varied among studies, which might have been caused by cow behavior, calf vitality, and distance from udder to floor.

Selman et al. (1970) observed the behavior of 30 calves during the first 8 h postpartum. Dams were categorized as beef cows, dairy heifers, and dairy cows. They were then sorted into 2 categories of “good-shaped” and “poor-shaped” according to udder conformation. Calves were evaluated prior to standing and teat-seeking. For teat-seeking activities, calves were compared from cows with good and poor udder shape for mean first suckling time. First suckling time was measured from the time the calves stood to when the calves found the teats of the cows and began to suck. Cows with good udders had calves with lower ($P < 0.02$) total teat-seeking time (17.1 vs. 39.6 minutes) than those with poor udders. The time from when the calf hit the ground to the time of the calf's first suckle was lower ($P < 0.01$) for calves from dams with good udders (79.4 minutes) than those calves born from cows with poor udders (220.1 minutes). This estimate does not include calves from six dairy heifers with good shaped udders. Reasons for excluded those calves were dams rejecting their calves, calves weakened after struggling to get footing when born on very slippery surface, and weak teat-seeking drive. The authors did not state if those calves with bad uddered dams took longer to stand up than those calves from good uddered dams. The time taken by calves to first suckle was faster ($P < 0.01$) for beef cows than the other 2 groups.

MacNeil and Mott (2006) used Line 1 Hereford cattle maintained by the USDA-ARS at Miles City, Montana to evaluate variation in calf gain from birth to weaning, milk production, and udder scores of cows. Udder scores were determined subjectively by scoring on a 1-to 9 scale using a pictorial reference provided by the American Hereford Association. Estimate of heritability for udder score was 0.23 ± 0.05. Weigh-suckle-weigh (WSW) was used as a means to determine milk production. The correlation between WSW with maternal preweaning gain was 0.80 ± 0.08. The correlation between WSW with udder score was -0.36 ± 0.16 which suggested smaller, tighter udders tended to produce less milk. The authors concluded that selection solely for increased maternal preweaning gain or milk production may result in degradation of udder quality and conformation.

Fiss and Wilton (1992) used various breeds of beef cattle in 4 different breeding systems over an 8 yr period to determine associations of cow weight and milk yield with other characteristics within the different breeding systems. Records were kept on 216 cows with 469 calvings and on 183 first-calf heifers. The cattle were divided into one of 4 breeding systems: Hereford, small rotation, large rotation, and Angus-large rotation. The Hereford group was made up of straightbred Hereford cattle. The small rotation group had Angus, Gelbvieh, Pinzgauer, and Tarentaise. The large rotation group was composed of Charolais, Maine-Anjou, and Simmental. The Angus-large rotation group consisted of animals from Angus sires on large rotation heifers. They found breed differences for weight of cow at weaning, milk yield, milk fat percentage, feed intake, and pregnancy rate. Similarly, they found that heavier cows had higher body condition, milk yield, and feed intake within all the breeding systems except Hereford. They did not see any differences ($P > 0.05$) among breeding systems in association between feed intake and weight or feed intake and milk yield, and believed that this was due to the cows all being fed to production requirements. Measurements were kept mainly on cows, and no growth characteristics for calves were incorporated. Also, nothing was stated as to the condition of the cow's udders or teats.

Day et al. (1987) performed 2 experiments to determine the effect of level of milk production on suckling behavior. Six Hereford x Angus and 5 Milking Shorthorn x Angus cows and their calves were used in the first experiment and 10 Hereford x Angus and 10 Milking Shorthorn x Angus cows from the same herd as those used in the first experiment were used in the second experiment. In the first experiment, suckling behavior was observed at 3 stages of lactation (averaging 52, 104, and 167 d postpartum). At each stage the 11 cow-calf pairs were observed for two 24 h periods separated by 24 h without observation. In the second experiment the 20 cow-calf pairs were evaluated much the same as in the first study. In this experiment, however, the pairs were observed for only one 24 h period and at an average of 17, 38, 59, and 80 d postpartum. The results from the first experiment indicated that as stage of lactation progressed, the frequency of nursing and total minutes nursed declined significantly. The duration of nursing period did not change significantly, but tended to increase in length as stage of lactation increased. The authors found interactions between frequency of nursing and milk production ($P < 0.03$) and frequency of nursing and total minutes nursed ($P < 0.10$). Similar results were found in the second experiment with frequency of nursing and total minutes nursed declining as lactation progressed and with no change in the duration of nursing. The frequency of nursing declined ($P < 0.01$) as the milk production level increased but the interaction of production level with stage of lactation was not significant. The authors did, however, find an interaction between milk production level and total minutes nursed ($P < 0.10$).

Disposition

Disposition (temperament) in cattle affects several aspects of production such as ease of handling and safety of workers (Grandin, 1993), growth and immune function (Fell et al., 1999), and milk production (Breuer et al., 2000). Major differences in disposition have been observed between breeds of cattle. In an early review, Cartwright (1980) noted differences in Zebu cattle as compared to European cattle in both temperament and intelligence. He stated that temperament was a concern in Brahman cattle, as they were noted for their response to human contact as well as their athletic ability.

In another review, Burrow (1997) evaluated the relationship of different measurements of temperament and performance. One study showed that animals with ¼ or ½ Brahman influence had poorer temperaments than did their British cross counterparts. Another study concluded Brahman cattle had longer flight distances than British cattle, suggesting more fear of humans. A third study stated Brahman crosses had poorer temperaments than Africander crosses which in turn had poorer temperaments than British crosses.

Heritabilities of temperament are low to moderate (Morris et al., 1994; Burrow and Corbet, 2000), when estimated using electronic flight score records from animals less than 18 mo of age. Cafe et al. (2011) reported Brahman cattle that were less docile had lower ($P < 0.05$) growth rates. This relationship was not seen in Angus cattle. Prayaga (2003) measured flight score on British breeds, Sanga derived breeds, Continental breeds, Zebu and Zebu crosses. Breed composition was found to be significant, but there was no clear trend for different breeds.

Cow disposition is important for producers that weigh and identifying newborn calves shortly after parturition. They must come into close proximity and interact with cows during a time of stress usually in an open space. Measuring disposition in young (less than 18 months of age) cattle within confined working facilities is not the same as cow disposition at calving in a relatively unconfined environment. However, Funkhouser

(2008) reported disposition at calving for first calf heifers to be low to moderately correlated with other measures of temperament at younger ages. Other than findings by Funkhouser (2008), which includes data from this study, there is very little literature that reports cow disposition at calving.

Calf Growth

Birth weight is an important trait to producers. High birth weights impact beef cattle operations due to an increase in dystocia, which can lead to calf and/or cow mortality, reduced performance, and decreased cow fertility (Paschal et al., 1991; Cundiff et al., 1995). There is a threshold point where increases in birth weight increase the incidence of dystocia, causing increases in calf mortality (Cundiff et al., 1995). Paschal et al. (1991) noted that, because of the close association between birth weight and dystocia, breeds with large differences between sexes for birth weight can experience higher levels of dystocia when compared to the expected level determined by the average birth weight of the breed. The birth weight differences between sexes in *Bos indicus*-sired calves out of *Bos taurus* cows is larger than that of *Bos taurus*-sired calves. When *Bos indicus* bulls are bred to *Bos taurus* heifers or small cows, large birth weights and increased incidence of dystocia is likely to occur (Roberson et al., 1986). However, this is not noticed with calves out of *Bos indicus*-sired females. Riley et al. (2001a) noted that calves out of Gir and Nellore cross females (34.8 kg and 36.7 kg, respectively) were lighter than those out of Angus, Gray Brahman, Red Brahman, and Indu-Brazil sired cows (39.4 kg, 37.1 kg, 37.2 kg, and 37.2 kg, respectively). Additionally, Jenkins and Ferrell (2004) reported calves out of Brahman sired females were lighter than calves out of cows sired by British bulls.

Weaning weight is important to producers because it represents, in most cases, the sale weight of the calf and revenue generating component of an operation. However, as with most things, too much emphasis on a single trait can be detrimental to production sustainability. Weaning weight is a combination of birth weight with preweaning gain. Preweaning gain is affected by the animal's direct growth potential and aggregate of maternal factors contributed by the dam.

In a review, Franke (1980) reported advantages in weaning weights of F_1 Brahman-British calves from 7 kg to 26 kg in relation to parental averages. Backcross calves from F_1 Brahman-Hereford cows weighed 19% more than straight bred calves. This increase in weaning weight was attributed to the maternal heterosis of the F_1 dam. McCarter et al. (1991) reported weaning weights of calves increased (226 kg to 237 kg) as the age of the cow increased from 3 to 5 years old. These authors also stated that the adjusted weaning weights increased as the proportion of Brahman increased.

CHAPTER III

METHODS AND MATERIALS

Data were collected from cows and calves at the Texas AgriLife Research Center at McGregor in the McGregor Genomics Project. All procedures involving animals were approved by the Texas A&M University Institutional Animal Care and Use Committee (AUP # 2008-234). The cows in this study were born in both spring and fall of 2003, 2004, 2005, and 2006, and spring of 2007 seasons. The calves in this study were born in both spring and fall of 2005, 2006, 2007, and 2008, and the spring 2009. The spring born calves were weaned in late-September or early to mid-October of the same year. The fall born calves were weaned in late-March or April of the following year. All calves were then sold or used in another study.

All heifers were exposed to bulls to calve at 2 years of age. Those fall-born heifers that did not conceive and calve at 2 years of age were managed with spring calving herds and exposed to bulls to calve at 2.5 years of age in the spring. Those fall-born heifers that calved at 2.5 yr of age were not penalized, in terms of calving record, for failing to calve at 2 yr of age. Cows were removed from the herd after second failure to wean a calf. Nine cows calved at 2 years of age in the fall: one in 2003, two in 2004, two in 2005, and four in 2006. Of those nine calves born, six were successfully weaned.

Cows were daughters of 4 different sires and belonged to one of 17 families. All 4 sires of the cows in the study were F_1 Nellore-Angus, where breed of sire is listed first. The cows in family numbers 70 to 77 and 80 to 84 were all produced by embryo transfer (ET) and are full siblings to others in their family. The dams of those cows were also F_1

Nellore-Angus. Cows in families 95 to 98 were all produced via natural service (NS) from the same 4 sires as the ET cows and are half siblings to others in their families. The dams of those cows were either half Brahman and half Angus, or half Brahman and half Hereford. All dams of the cows in families 95 to 98 were either of the F_1 or F_2 generation. Females were born at McGregor, except for 10 of the 2003-spring born cows which came in late spring of 2003 from the Texas A&M Agricultural Research Center at Angleton. Heifers that were to become cows in this project were mostly born in the spring calving season with the exception of 69 ET females that were born in the fall calving seasons of 2003, 2004, 2005, and 2006. From the 2004 to 2008 breeding season the cows were pastured within age group together and handled the same. Heifers were managed separately every year. Angus bulls were used to produce most of the calves in this study and were bred to all cows for their first calf. In 2008 the 2006 spring-born cows were bred to F_2 Nellore-Angus bulls (sons of 551G and 297J were bred to daughters of 432H and 437J, and vice versa). All NS cows were bred to F_1 Nellore-Angus bulls in 2008.

Cows were kept on various warm season pastures including coastal bermuda, Eastern Gama grass, Kleingrass, and native pastures. In the spring and summer they were supplemented with mineral and salt. In the winter they were supplemented with coastal bermuda hay or sudan hybrid hay.

At birth, cows and calves were evaluated for several different traits including BWT, udder support scores, teat length and diameter, and disposition scores. These traits, with the exception of BWT, were subjectively evaluated by trained TAMU personnel at the McGregor research center. Calving data were generally recorded within 24 hr postpartum. The methods of scoring udders and measuring teats are consistent with those used by Riley et al. (2001b). Udder support scores ranged from 1 to 9 with 1 being very loose and pendulous and 9 being very tight. Udder support relates to the degree and strength of the front and rear udder attachment. In addition, all 4 teat lengths and diameters were individually recorded as subjective estimates from a single evaluator. Teat diameter was estimated at the midpoint of the teat. Teat length was estimated between the upper and lower extremity of the teat. On many cows the point at which the udder stops and the teat begins is not easy to determine but every effort was made to be consistent in what was considered the upper extremity of the teat. When processing calves at birth, disposition of the cow was scored on a 1 to 5 scale with 1 being calm and 5 being very nervous, wild, or crazy based on behavior. At weaning, the weights and BCS of calves and cows were recorded. Body condition score is a subjective estimate with a range from 1 to 9 with 1 being extremely thin or emaciated and 9 being very obese (Wagner et al., 1988). Data entry for CR and WR consisted of the cow receiving a 1 for successfully calving or weaning a calf and a 0 for failure.

Statistical Analysis

Three sets of analyses corresponding to data grouping were conducted. Data grouping included ET full sibling cows, NS half sibling cows, and all cows together analyzed as paternal half siblings (PHS). In all models, cow age categories consisted of 2 yr olds, 3 yr olds, and 4 through 6 yr olds.

Embryo Transfer Full-Sib Cows in Families 70 to 77 and 80 to 84. Effects included in the analysis of ET cows were sire of cow, family nested within sire of cow, season of cow birth, and age of cow nested within year of calf birth. Cow nested within family was included as a random effect. Sex of calf birth was included in the analyses of BWT, WWT, PW ADG, and calf BCS. Cow age was included for disposition rather than cow age nested within calf year of birth. For CW and cow BCS, 2 level class variables were included for the effect of a perfect calving record (1 = never missed and 0 = missed at least once) and lactation status (lactating versus not lactating) as of July 1st of the year. The data from the 9 fall born cows that calved at 2 yr of age were included in CR and WR analyses to confirm the cow could conceive and raise the calf but omitted from analyses of BWT, WWT, and PW ADG.

Natural Service Cows in Families 95 to 98. Effects that were included in the analysis of NS cows are sire of cow and age of cow nested within year of calf birth. Cow nested within sire and dam of cow nested within dam breed type were included as random effects. Sex of calf was included in BWT, WWT, PW ADG, and calf BCS. As in the ET analysis, cow age was included for disposition rather than cow age nested within calf year of birth. For CW and cow BCS, two level class variables, described above, were included for effect of a perfect calving record and lactation status as of July 1st of the year.

Paternal Half-Siblings - All Cows Combined. Effects that were included in the analysis of all cows combined as PHS were sire of cow, season of cow birth, and age of cow nested within year of calf birth. Cow nested with family and dam of cow nested within dam breed type were included as random effects. Sex of calf was included in the analyses of BWT, WWT, PW ADG, and calf BCS. Cow age was included for disposition rather than cow age nested within calf year of birth. For CW and cow BCS, two level class variables, described above, were included for effect of a perfect calving record and lactation status as of July 1st of the year.

Pearson correlation coefficients among all traits were evaluated in all analyses. Regressions of WWT of calf on weaning age in days were evaluated for the 3 datasets. Least squares means were separated by *t*-tests when a significant *F*-test was observed using the MIXED procedure (SAS Inst. Inc., Cary, NC). Calving rate and WR were analyzed as the proportion of calves successfully born and weaned of those cows exposed to bulls, respectively. In addition, residuals were calculated on all cows in the 3 analyses but not reported in this manuscript.

Cooper et al. (2009) reported direct effects for BWT, WWT, and gestation length on the F_2 cows in the current study and their male counter-parts as calves. Funkhouser (2008) reported disposition scores on these cows at weaning and their first calving season. Gladney (2008) reported udder and teat characteristics, calf growth, and reproduction from cows in this study through the spring 2007 calving season. Updated data through the 2009 calves were analyzed in the current study.

CHAPTER IV

RESULTS AND DISCUSSION

A list of the number of calves by sire of the cow and family number is given in Table 1. The cows from the 13 groups of full sibs (embryo transfer dams) were responsible for 451 calves born from 2005 to 2009 and the cows from the 4 groups of half sibs (natural service dams) had 263 calves. A list of the number of calves by dam type, parity, and sex of calf is in Table 2. Data were available on 714 calves: 23

Table 1. Number of calves born by calving year, sire of cow, and family

Sire of cow	Family	Calving Year					
		2005	2006	2007	2008	2009	Total
297J	70	1	5	7	12	11	36
	71	2	6	13	16	22	59
	95	1	8	11	18	19	57
432H	72	2	9	11	13	12	47
	73	0	2	1	2	2	7
	82	0	0	2	6	6	14
	96	6	11	34	51	42	144
437J	74	3	2	3	3	4	15
	75	3	5	10	12	14	44
	81	1	7	12	16	15	51
	83	0	2	13	15	15	45
	97	0	2	4	9	17	32
551G	76	0	2	1	1	1	5
	77	0	5	13	16	13	47
	80	0	6	13	14	20	53
	84	0	0	8	9	11	28
	98	4	6	6	7	7	30
Total		23	78	162	220	231	714

Table 2. Number of calves born by parity, sex, and type of dam

Dam Type	Parity	Female	Male	Unknown	n
Full sibs (ET)	1	85	78	1	164
	2	66	61	2	129
	3	45	57	0	102
	4	31	17	0	48
	5	2	6	0	8
					451
Half sibs (NS)	1	53	37	1	91
	2	43	37	0	80
	3	22	34	0	56
	4	12	13	1	26
	5	4	6	0	10
					263
Total		363	346	5	714

spring and fall-born 2005 calves from first parity cows, 78 spring and fall-born 2006 calves from first and second parity cows, 162 spring and fall-born 2007 calves from first, second, and third parity cows, 220 spring and fall-born 2008 calves from first, second, third, and fourth parity cows, and 231 spring-born 2009 calves from first, second, third, fourth, and fifth parity cows. Calves were out of 302 different cows (188 ET and 114 NS) that were born from 2003 to 2007. Of the 714 calves, 363 were female, 346 were male, and 5 could not be determined due to death and other complications at birth. A total of 255 calves were out of first parity cows, 209 calves came from second parity cows, 158 calves were from third parity cows, 74 calves were from fourth parity cows, and 18 calves were from fifth parity cows.

Table 3. Simple means for traits measured among full sibling (embryo transfer) families

Trait[1]	N	Mean	Standard Deviation	Minimum	Maximum
CR	514	0.88	0.33	0.00	1.00
WR	514	0.81	0.39	0.00	1.00
BWT	446	30.80	4.70	18.00	45.90
WWT	414	202.20	33.20	110.30	309.60
PW ADG	414	0.96	0.13	0.59	1.40
AVTL	445	3.90	1.30	1.70	10.20
AVTD	445	2.10	0.60	1.30	6.20
USUP	445	6.60	0.70	4.00	8.00
DISP	445	2.50	1.20	1.00	5.00
CW	497	451.80	58.30	319.50	650.30
Cow BCS	497	5.40	0.50	4.00	7.00
Calf BCS	411	5.60	0.50	4.00	6.00

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning (kg), Cow BCS = Cow body condition score, Calf BCS = Calf body condition score.

Table 4. Simple means for traits measured among half sibling (natural service) families

Trait[1]	N	Mean	Standard Deviation	Minimum	Maximum
CR	311	0.84	0.36	0.00	1.00
WR	311	0.79	0.41	0.00	1.00
BWT	257	30.30	5.50	17.10	50.40
WWT	246	198.00	32.50	99.90	297.90
PW ADG	246	0.97	0.15	0.59	1.90
AVTL	257	4.00	1.50	1.50	8.70
AVTD	257	2.10	0.70	1.40	5.70
USUP	257	6.40	0.80	4.00	9.00
DISP	257	2.10	1.20	1.00	5.00
CW	303	446.20	60.50	316.80	670.50
Cow BCS	311	5.40	0.50	4.00	6.00
Calf BCS	246	5.40	0.50	4.00	6.00

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning (kg), Cow BCS = Cow body condition score, Calf BCS = Calf body condition score.

Simple means for traits in the analyses including CR, WR, cow disposition score at calving (DISP), average teat length (AVTL), average teat diameter (AVTD), udder support score (USUP), BWT, WWT, and PW ADG, cow BCS at weaning, calf BCS at weaning, and CW are shown in Tables 3, 4, and 5 for ET, NS, and PHS, respectively. Simple means for all traits listed above of ET cows by sire of cow are in Table 6 and by family are in Table 7. The results are presented by trait of study. The *P*-values

Table 5. Simple means for traits measured among all cows combined (paternal half siblings)

Trait[1]	N	Mean	Standard Deviation	Minimum	Maximum
CR	816	0.86	0.34	0.00	1.00
WR	816	0.80	0.39	0.00	1.00
BWT	694	30.60	5.00	17.10	50.40
WWT	654	200.60	32.40	99.90	309.60
PW ADG	654	0.96	0.14	0.59	1.90
AVTL	695	3.90	1.40	1.50	10.20
AVTD	695	2.10	0.60	1.30	6.20
USUP	695	6.60	0.70	4.00	9.00
DISP	695	2.40	1.20	1.00	5.00
CW	798	449.70	59.20	316.80	670.50
Cow BCS	798	5.40	0.50	4.00	7.00
Calf BCS	654	5.40	0.50	4.00	6.00

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning (kg), Cow BCS = Cow body condition score, Calf BCS = Calf body condition score.

Table 6. Simple means of full sibling (embryo transfer) cows by sire of cow

	Sire of Cow			
Trait[1]	297J	432H	437J	551G
CR	0.84	0.87	0.91	0.88
WR	0.80	0.82	0.84	0.79
BWT	30.4	30.3	30.6	31.4
WWT	208.5	197.5	198.3	200.4
PW ADG	0.99	0.95	0.95	90.5
Cow BCS	5.37	5.36	5.39	5.43
Calf BCS	5.52	5.35	5.41	5.51
CW	442.9	436.0	456.1	461.8
AVTL	4.1	3.2	3.6	4.3
AVTD	2.0	2.0	1.9	2.2
USUP	6.5	6.6	6.9	6.4
DISP	1.8	2.3	2.9	2.8

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition score, CW = Cow weight at weaning (kg), Cow BCS = Cow body condition score, Calf BCS = Calf body condition score.

Table 7. Simple means of full sibling (embryo transfer) cows by family

		Trait[1]					
Family	Sire	CR	WR	DISP	BWT	WWT	PW ADG
70	297J	0.86	0.79	2.30	31.0	212.9	0.99
71	297J	0.83	0.80	1.41	36.7	210.1	0.99
72	432H	0.84	0.79	2.28	30.8	202.2	0.95
73	432H	0.88	0.75	1.43	29.0	200.4	0.90
82	432H	1.00	1.00	2.57	29.3	179.8	0.86
74	437J	0.94	0.94	2.73	31.8	213.7	1.04
75	437J	0.88	0.82	3.00	28.8	195.4	0.95
81	437J	0.91	0.82	2.92	30.9	198.5	0.95
83	437J	0.92	0.84	2.78	31.5	195.3	0.93
76	551G	0.63	0.63	2.60	30.6	206.8	0.99
77	551G	0.90	0.87	2.53	30.8	194.6	0.95
80	551G	0.87	0.79	2.81	32.0	205.7	0.99
84	551G	0.90	0.71	3.07	31.2	199.0	0.94

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d) Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition.

Table 7 cont.

		Trait[1]					
Family	Sire	Cow BCS	Calf BCS	CW	AVTL	AVTD	USUP
70	297J	5.36	5.45	432.7	4.01	2.13	6.50
71	297J	5.38	5.55	444.7	4.27	1.98	6.54
72	432H	5.36	5.30	421.6	3.15	2.03	6.54
73	432H	5.50	5.50	514.6	3.81	1.85	7.14
82	432H	5.29	5.46	446.9	3.00	1.85	6.64
74	437J	5.38	5.6	457.8	3.51	2.00	6.80
75	437J	5.38	5.38	458.7	3.71	2.00	6.84
81	437J	5.37	5.37	443.3	3.51	1.85	6.96
83	437J	5.41	5.41	467.0	3.68	1.93	6.82
76	551G	5.00	5.20	440.2	5.05	2.31	6.80
77	551G	5.36	5.48	443.5	3.96	2.11	6.40
80	551G	5.50	5.60	490.3	4.27	2.34	6.40
84	551G	5.48	5.45	439.7	4.83	2.24	6.50

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight (kg), WWT = Weaning weight (kg), PW ADG = Preweaning average daily gain (kg/d), Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg), AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score, DISP = Disposition.

(probability values) from the analyses of variance are presented in Tables 8, 9, and 10 for ET, NS, and PHS, respectively.

Calving Rate

Embryo Transfer Cows. Least squares means for CR are in Table 11. Sire of cow was not significant; however, there were important numerical differences among averages. Daughters of 437J were higher than daughters of 551G (0.92 versus 0.81). Daughters of 297J and 432H had calving rates of 0.87 and 0.91, respectively (Table 11). Within sire 551G, family 76 is numerically small and had a large effect on this least squares mean. Daughters of 437J had the highest CR. This agrees with Gladney (2008)

Table 8. *P*-values and residual variance estimates for traits among full sibling (embryo transfer) cow families

	Trait[1]					
Effect	CR	WR	AVTL	AVTD	USUP	DISP
Sire of cow	0.15	0.13	< 0.001	0.08	0.005	< 0.001
Family (sire of cow)	0.25	0.24	0.09	0.50	0.55	0.12
Cow age (calf year of birth)	0.02	0.003	< 0.001	< 0.001	< 0.001	.
Age of cow	.	.	.	.	.	0.06
Season of cow birth	0.14	0.02	0.04	0.006	0.20	0.77
Residual variance	0.11	0.14	0..46	0.17	0.24	0.73

[1] CR = Calving rate, WR = weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 8 cont.

Effect	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW
	Trait[1]					
Sire of cow	0.37	0.009	0.02	0.25	0.39	0.46
Family (sire of cow)	0.36	0.03	0.03	0.35	0.14	0.02
Cow age (calf year of birth)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sex of calf	< 0.001	< 0.001	< 0.001	.	0.15	.
Season of cow birth	0.49	0.004	0.01	0.03	0.28	0.02
Calving record	.	.	.	0.74	.	0.96
Lactation status	.	.	.	< 0.001	.	< 0.001
Calf age at weaning	.	< 0.001	.	.	.	.
Residual variance	13.76	1.94	0.004	0.19	0.085	392.23

[1] CR = Calving rate, WR = weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 9. *P*-values and residual variance estimates for traits from half sibling (natural service) cow families

	Trait[1]					
	CR	WR	AVTL	AVTD	USUP	DISP
Effect						
Sire of cow	0.32	0.35	< 0.001	0.015	0.005	0.22
Cow age (calf year of birth)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	.
Age of cow	.	.	.	.	.	0.02
Residual variance	0.12	0.14	0.46	0.20	0.03	0.63

[1] CR = Calving rate, WR = Weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 9 cont.

	Trait[1]					
	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW
Effect						
Sire of cow	0.12	0.24	0.20	0.48	0.50	0.78
Cow age (calf year of birth)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sex of calf	0.12	< 0.001	< 0.001	.	0.66	.
Calving record	.	.	.	0.26	.	0.12
Lactation status	.	.	.	< 0.001	.	< 0.001
Calf age at weaning	.	< 0.001	.	.	.	.
Residual variance	17.58	279.19	0.008	0.15	0.16	559.78

[1] CR = Calving rate, WR = Weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 10. *P*-values and residual variance estimates for traits from all cows combined (paternal half siblings)

	Trait[1]					
	CR	WR	AVTL	AVTD	USUP	DISP
Effect						
Sire of cow	0.34	0.53	< 0.001	0.004	< 0.001	0.005
Season of cow birth	0.13	0.02	0.09	0.08	0.72	0.82
Cow age (calf year of birth)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	.
Age of cow	.	.	.	.	.	0.08
Residual variance	0.11	0.14	0.53	0.20	0.25	0.70

[1] CR = Calving rate, WR = Weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 10 cont.

Effect	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW
	Trait[1]					
Sire of cow	0.17	0.04	0.09	0.54	0.34	0.65
Season of cow birth	0.80	0.09	0.23	0.10	0.08	0.002
Cow age (calf year of birth)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sex of calf	< 0.001	< 0.001	< 0.001	.	0.19	.
Calving record	.	.	.	0.28	.	0.47
Lactation status	.	.	.	< 0.001	.	< 0.001
Calf age at weaning	.	< 0.001	.	.	.	.
Residual variance	15.62	227.6	0.006	0.18	0.12	505.25

[1] CR = Calving rate, WR = Weaning rate, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition score, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning ADG, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight.

Table 11. Least squares means and standard errors of calving rate, weaning rate, and disposition among full sibling (embryo transfer) cow families for sire of cow, family, cow age, and season of cow birth effects

Effect		CR[1]	WR[1]	DISP[1]
Sire of cow				
	297J	0.87 ± 0.04	0.85 ± 0.05	1.89 ± 0.16^{a}
	432H	0.91 ± 0.06	0.87 ± 0.07	2.07 ± 0.26^{a}
	437J	0.92 ± 0.0	0.89 ± 0.04	2.77 ± 0.16^{b}
	551G	0.81 ± 0.0	0.75 ± 0.05	2.79 ± 0.20^{b}
Family(sire of cow)				
	70 297J	0.88 ± 0.05	0.83 ± 0.07	2.36 ± 0.26
	71 297J	0.85 ± 0.04	0.86 ± 0.05	1.43 ± 0.19
	72 432H	0.86 ± 0.05	0.84 ± 0.06	2.29 ± 0.25
	73 432H	0.83 ± 0.12	0.68 ± 0.15	1.40 ± 0.65
	82 432H	1.04 ± 0.09	1.07 ± 0.11	2.54 ± 0.39
	74 437J	0.94 ± 0.08	0.95 ± 0.10	2.65 ± 0.47
	75 437J	0.88 ± 0.05	0.84 ± 0.06	2.88 ± 0.24
	81 437J	0.92 ± 0.05	0.87 ± 0.06	2.76 ± 0.23
	83 437J	0.93 ± 0.06	0.89 ± 0.07	2.77 ± 0.23
	76 551G	0.58 ± 0.12	0.55 ± 0.15	2.72 ± 0.68
	77 551G	0.90 ± 0.05	0.88 ± 0.06	2.51 ± 0.23
	80 551G	0.86 ± 0.05	0.79 ± 0.06	2.78 ± 0.22
	84 551G	0.92 ± 0.07	0.79 ± 0.08	3.15 ± 0.28
Cow age (calf birth year)				Cow age
	2 2005	0.93 ± 0.09	0.94 ± 0.11	2 2.28 ± 0.11
	2 2006	0.88 ± 0.05	0.82 ± 0.06	3 2.35 ± 0.12
	3 2006	0.77 ± 0.10	0.77 ± 0.12	4-6 2.52 ± 0.12
	2 2007	0.94 ± 0.05	0.90 ± 0.06	
	3 2007	0.89 ± 0.05	0.86 ± 0.06	
	4-6 2007	1.02 ± 0.10	1.02 ± 0.12	
	2 2008	0.84 ± 0.06	0.75 ± 0.07	
	3 2008	0.89 ± 0.05	0.82 ± 0.06	
	4-6 2008	0.95 ± 0.05	0.94 ± 0.05	
	2 2009	0.77 ± 0.06	0.63 ± 0.07	
	3 2009	0.71 ± 0.06	0.64 ± 0.07	
	4-6 2009	0.89 ± 0.03	0.80 ± 0.04	
Season of cow birth				
	Fall	0.90 ± 0.04	0.88 ± 0.04^{a}	2.36 ± 0.14
	Spring	0.85 ± 0.03	0.77 ± 0.04^{b}	2.41 ± 0.13

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).
[1] CR = Calving rate, WR = Weaning rate, DISP = Disposition.

who reported simple means in a preliminary analysis of heifer reproductive performance for these ET cows. Daughters out of bull 551G were the lowest for CR.

Family nested within sire of cow was not significant for CR. The least squares means for family nested within sire for ET cows are in Table 11. Family 76 (0.58) was the lowest. Families 73 and 76 had only 7 and 5 total born calves, respectively. Within sire 432H, family 82 (1.04) was higher than family 72 (0.86). Within sire 551G, family 76 was lower than family 77 (0.90).

Gladney (2008) reported 8 ET families that had a CR (simple means) of 1.00 for their first calf. Three of those families, 76, 77, 84, were sired by 551G. Also, 2 of those families, 75 (by 437J) and 77 (by 551G), had over 10 heifers. In that earlier analysis, the lowest CR among ET families was for family 70 (0.75) sired by 297J.

The effect of cow age nested within calf year of birth was important ($P < 0.05$) Least squares means for cow age nested within calf birth year are in Table 11. There was a trend that as cow age increased they tended to record higher CR. This may be due, in part, to when cows reach the 4 to 6 yr age category in this study they have had chance for failure to wean a calf for the second time. Data are then collected from remaining cows that have not skipped more than one calf. Also, cows raising their first calf as two yr olds are still growing and are typically under more nutritional stress than older cows. This is a larger effect for spring born cows that are actually 2 yr old than for fall born cows that have their first calf in the spring when they are about 2.5 yr of age. Note that the nine fall born cows that calved in the fall were not exposed to bulls again until the following May,

Table 12. Least squares means and standard errors of calving and weaning rate and disposition among half sibling (natural service) cows for sire and age of cow effects

Effect		CR[1]	WR[1]		DISP[1]
Sire of cow					
	297J	0.82 ± 0.05	0.77 ± 0.06		2.39 ± 0.23
	432H	0.88 ± 0.04	0.85 ± 0.04		1.97 ± 0.14
	437J	0.95 ± 0.06	0.91 ± 0.07		2.13 ± 0.27
	551G	0.86 ± 0.06	0.85 ± 0.08		2.50 ± 0.37
Cow age (calf birth year)				Cow age	
	2 2005	1.01 ± 0.11	1.00 ± 0.12	2	2.10 ± 0.15^{a}
	2 2006	0.92 ± 0.08	0.92 ± 0.09	3	2.38 ± 0.15^{b}
	3 2006	0.91 ± 0.11	0.90 ± 0.12	4-6	2.28 ± 0.15^{ab}
	2 2007	0.81 ± 0.06	0.68 ± 0.07		
	3 2007	0.77 ± 0.08	0.68 ± 0.09		
	4-6 2007	1.01 ± 0.11	1.00 ± 0.12		
	2 2008	0.63 ± 0.06	0.61 ± 0.07		
	3 2008	0.97 ± 0.06	0.83 ± 0.07		
	4-6 2008	0.98 ± 0.07	0.98 ± 0.07		
	2 2009	0.56 ± 0.10	0.57 ± 0.12		
	3 2009	0.68 ± 0.06	0.65 ± 0.07		
	4-6 2009	0.97 ± 0.05	0.94 ± 0.05		

^{a,b} Means in the same column without a common superscript differ (P < 0.10).
[1] CR = Calving rate, WR = Weaning rate, DISP = Disposition score.

after their calves were weaned. Therefore a higher CR would be expected in the older cows.

Season of cow birth affected CR (P = 0.14). Fall-born cows tended to be higher than spring-born cows (Table 11). This could be due to the fact that all fall-born cows calved as 2.5 yr olds in the spring (n = 60) with exception of the nine that calved as 2 yr old in the fall. Gladney (2008) reported heifers that were allowed to calve first at 2.5 years had a higher CR (0.941) than did those that calved first as 2 yr olds (0.897). Gladney (2008), however, did not include the 9 fall born heifers that calved at 2 yr of age in the fall in his analyses. Note that a fall born heifer was given credit for calving as a two yr old if she calved either in the fall (when she was actually 2 yr old) or in the spring when she was about 2.5 yr of age.

Natural Service Cows. Least squares means for CR for NS are in Table 12. Sire of cow was not significant. Daughters of 437J (0.95) had the highest CR and daughters out of bull 297J (0.82) had the lowest. Least squares means for daughters of 432H and 551G were 0.88 and 0.86, respectively.

Cow age nested within calf year of birth affected CR in NS cows ($P < 0.05$). Least squares means for cow age nested within calf birth year are in Table 12. There was a trend that as cow age increased they tended to have higher CR. As discussed in the section for ET cows, this may be due, in part, to previous culling and/or the lactational stress on young cows. Also, these NS cows had to conceive as yearling heifers to calve as two year olds.

Gladney (2008) reported heifers that were out of half Brahman, half Angus dams had a lower calving rate (0.846) than those from half Brahman, half Hereford dams (0.897). In the current study, dam of cow nested within dam breed type was included in the model in preliminary analysis but was not significant. Cundiff (2005) reported that 2 yr old heifers sired by Brahman had a CR of 0.74, but heifers from Nellore sires had a CR of 0.90 (these were not born in the same years, and calved at 2 yr of age). In contrast, Riley et al. (2001a) found that 2 yr old Nellore-sired females had a CR of 0.96 and Brahman-sired females were 0.95 (these calved at 2.5 yr of age).

Paternal Half Siblings. Least squares means for CR from the PHS analysis are in Table 13. Sire of cow was not significant. However, there were important numerical differences among averages. Daughters of 437J had the highest CR (0.92) and those of 297J had the lowest (0.86). Daughters of bulls 432H and 551G were 0.90 and 0.88.

Cow age nested within calf year of birth affected CR ($P < 0.05$).

Least squares means for cow age nested within calf birth year are in Table 13. As discussed above, as cow age increased CR tended to do so as well.

Season of cow birth affected CR in PHS ($P = 0.13$). Fall born cows tended to be higher than spring born cows (Table 13). As discussed in the section for ET cows, this is due, at least primarily, to the fall born cows being allowed to calve either in the fall or spring (when they were about 2.5 yr of age) and subsequently kept in a spring calving season. Therefore, in the analyses, they were considered to be the same age as the spring born cows (that were born the following year), although they were about 6 mo older.

Weaning Rate

Embryo Transfer Cows. Least squares means for sire of cow among ET cows are in Table 11. Sire of cow was not significant. However there were important numerical differences among averages. The same trends for WR were seen as in CR. Daughters of 437J tended to have the highest WR among the four sires. Daughters of 437J (0.89) were higher than daughters of 551G (0.75), due almost entirely to the low value (0.58) for family 76, which was discussed earlier as being a numerically small family. Daughters of 297J and 432H had WR values of 0.85 and 0.87, respectively. Gladney (2008) reported

Table 13. Least squares means and standard errors of calving and weaning rate and disposition among all cows combined (paternal half sibling) for sire of cow, cow age, and season of cow birth effects

Effect	CR[1]	WR[1]		DISP[1]
Sire of cow				
297J	0.86 ± 0.03	0.84 ± 0.04		2.18 ± 0.18^{a}
432H	0.90 ± 0.03	0.87 ± 0.04		2.02 ± 0.14^{a}
437J	0.92 ± 0.03	0.89 ± 0.04		2.57 ± 0.17^{b}
551G	0.88 ± 0.03	0.84 ± 0.04		2.72 ± 0.18^{b}
Cow age (calf birth year)			Cow age	
2 2005	0.98 ± 0.07	0.99 ± 0.8	2	2.27 ± 0.10
2 2006	0.89 ± 0.04	0.85 ± 0.05	3	2.40 ± 0.11
3 2006	0.84 ± 0.07	0.86 ± 0.08	4-6	2.45 ± 0.11
2 2007	0.91 ± 0.04	0.83 ± 0.04		
3 2007	0.86 ± 0.04	0.81 ± 0.05		
4-6 2007	1.02 ± 0.07	1.04 ± 0.08		
2 2008	0.76 ± 0.04	0.71 ± 0.05		
3 2008	0.94 ± 0.04	0.84 ± 0.04		
4-6 2008	0.96 ± 0.04	0.96 ± 0.04		
2 2009	0.73 ± 0.05	0.63 ± 0.06		
3 2009	0.72 ± 0.04	0.68 ± 0.05		
4-6 2009	0.93 ± 0.03	0.86 ± 0.03		
Season of cow birth				
Fall	0.91 ± 0.03	0.90 ± 0.04^{a}		2.39 ± 0.15
Spring	0.86 ± 0.02	0.82 ± 0.02^{b}		2.36 ± 0.09

[a,b] Means in the same column without a common superscript differ (*P* < 0.10).
[1] CR = Calving rate, WR = Weaning rate, DISP = Disposition.

daughters of 437J had the highest WR in first calf heifers (simple means).

Family nested within sire was not significant for WR. However there were important numerical differences among averages. Least squares means by family among ET cows are in Table 11. Family 82 (1.07), a small family by bull 432H, was the highest of all families and was different from families 72 (0.84) and the very small family 73

(0.68), who are also sired by 432H. Family 76 (0.55) was the lowest of all families and was different from family 77 (0.88) that was also sired by 551G.

The effect of cow age nested within calf year of birth was important for WR ($P < 0.05$). Least squares means for WR among ET cows are in Table 11. As stated above for CR this may be due, in part, to when cows reach the 4 to 6 yr age category in this study they have had chance for failure to wean a calf for the second time. Data are then collected from remaining cows that have not skipped more than one calf. Therefore a higher WR would be expected in the older cows. Also, for the 2 yr old spring born cows, age at puberty can limit their ability to calve as 2 yr olds and, for those that do calve at two, the stress of lactation limits their ability to re-breed as 2 yr olds.

Fall born cows were higher ($P = 0.02$) than spring born cows (0.88 versus 0.77). As stated for CR, this is due to the fact that all fall born cows calved as 2.5 yr olds in the spring ($n = 60$) with the exception of nine that calved as 2 yr old in the fall. Gladney (2008) reported 2 yr old heifers WR of 0.83, whereas 2.5 yr old heifers had WR of 0.912 among the ET heifers. Riley et al. (2001a) reported that for females that calved at 2.5 yr of age, those with Nellore sires had WR of 0.96 and were significantly higher than those sired by Brahman (0.67) for their first potential calf crop.

Natural Service Cows. Sire of cow was not significant for WR. However there were important numerical differences among averages. The same trends for sire of cow were seen as in CR. Daughters of 437J (0.91) had the highest WR and were higher than daughters of 297J (0.77). Daughters of 432H and 551G both had WR values of 0.85

(Table 12). Gladney (2008) reported daughters of 297J (0.79) ranked the lowest when simple means for first calving heifers were calculated.

As in ET cows, cow age nested within calf year of birth affected WR ($P < 0.05$). There was a trend that as cows got older they tended to have higher WR (Table 12). As stated above, this may be due to previous culling, failure to conceive as yearling heifers, and/or the lactational stress on young cows.

In the current study, dam of cow nested within dam breed type was included in the model in a preliminary analysis but did not affect WR ($P = 0.93$). Gladney (2008) reported heifers out of Brahman-Angus dams had simple mean for WR of 0.85, and those out of Brahman-Hereford dams had WR of 0.82. This was a switch in order from CR as he reported that heifers out of Brahman-Hereford dams had a higher CR. Cundiff (2005) reported 2 yr old heifers with Nellore sires had WR of 0.73 and Brahman-sired heifers were 0.65, the lowest of any of the sire breeds in the study in Nebraska.

Paternal Half Siblings. Sire of cow was not significant. The same trends for WR were seen as in CR. Daughters of 437J tended to have the highest WR among the 4 sires. Least squares means for WR in PHS are in Table 13.

As in the other two analyses for WR, there was an effect of cow age nested within calf year of birth ($P < 0.05$). Least squares means for WR PHS are in Table 13. As in the analyses for ET and NS cows, there was a trend that as cow got older they tended to record higher WR.

As in the ET subset of the data, fall born cows had higher CR ($P = 0.02$) than spring born cows (0.90 versus 0.82, Table 13) in the PHS analysis.

Disposition

Embryo Transfer Cows. Sire of cow was significant. Least squares means for sire of cow are in Table 11. Daughters of sires 297J (1.89) and 432H (2.07) (note the effects of families 71 and, especially, the small family 73 on these least squares means) were more docile (P < 0.05) than daughters of sires 437J (2.77) and 551G (2.79).
Gladney (2008) reported that ET cows sired by 437J had the highest DISP at 2.9. Cows sired by 551G, 432H, and 297J had averages of 2.4, 2.0, and 1.7 in that earlier analysis.

Funkhouser (2008) evaluated DISP on the cows in the current study and the male counter-parts at weaning, on the steer counter-parts near the end of the finishing period, and when the cows had their first calf. At weaning, the overall disposition for calves by bulls 297J, 432H, 297J, and 551G were 2.62, 3.87, 3.58, and 4.48, respectively (includes steer counterparts, excludes bulls). The overall disposition for steers near the end of the feeding period by bulls 297J, 432H, 297J, and 551G were 2.77, 3.32, 3.57, and 3.79, respectively. Note that in the weaning and yearling evaluations, disposition was scored on a nine point scale rather than the five point scale used for scoring the cows. For first calf heifers produced by ET, sire of cow (P = 0.04) had an effect on DISP at calving, in that earlier analysis, as it did in the current analysis. Sire 432H was the lowest (most desirable) for DISP in first calf ET heifers. It was noted that 432H may have had a low score in first calf heifers due to a small number of heifers in family 73. Both 432H and 297J were significantly lower than 437J, which had the highest least squares mean DISP in first calf heifers, in that earlier analysis.

In ET cows, family nested within sire was not a significant effect on DISP. However there were important numerical differences among averages. Least squares means are in Table 11. Families 71 and 73 were the lowest (1.4 and 1.3, respectively) and family 84 (3.0) was the highest. It is important to note family 73 had only a total of 7 calvings out of 2 cows in this evaluation. Within sire 297J, family 70 (2.3) was higher (less desirable) than family 71. Within sire 551G, family 84 was higher than family 77 (2.4).

Funkhouser (2008), in the earlier analysis of DISP on the cows in the current study when they had their first calf, found family within sire of cow to be important (P = 0.08). Families 74, 75, and 81, all sired by 437J, had the highest average scores. Additionally, family 73, sired by 432H, was the lowest in that analysis, but it was noted there were only 2 first calf heifers in this family.

Cow age was important (P = 0.06). Two yr olds (2.3) were more docile than cows older than 4 old cows (2.5). Season of cow birth was not a significant source of variation for DISP.

Natural Service Cows. Sire of cow was not significant for DISP; however, daughters of sires 297J and 551G tended to be higher (less docile) than daughters of 432H and 437J (Table 12). Gladney (2008) reported those sired by 437J ranked the highest (least desirable) for disposition score (2.6), but cows sired by 297J ranked second (2.4). Two yr old cows (2.1) were more docile (P < 0.05) than 3 yr old cows (2.4), in the current analysis.

Paternal Half Siblings. Sire of cow was significant for DISP. The same was seen as in ET cows. Daughters of sires 297J (2.18) and 432H (2.02) were more docile (P < 0.10) than those of sires 437J (2.57) and 551G (2.72). Least squares means for sire of cow among PHS are in Table 13. Two yr old cows (2.3) were estimated to be slightly more docile than cows older than 4 yr old (2.5). Season of cow birth was not a significant source of variation in PHS.

Average Teat Length

Embryo Transfer Cows. Sire of cow was significant. Daughter of 297J (4.0 cm) and 551G (4.2) had longer (P < 0.05) AVTL than daughters of 432H (3.1 cm) and 437J (3.5 cm). Gladney (2008) reported that ET cows by 551G had longer (P < 0.10) AVTL than the other 3 sires with an average length of 3.7 cm. Additionally, cows by 297J (3.3 cm) had longer AVTL (P < 0.10) than those by 437J (2.9 cm) and 432H (2.7 cm), in that earlier analysis.

Family nested within sire was also important (P = 0.09). Least squares means for AVTL are in Table 14. Families 76 and 84, both sired by 551G, had the highest AVTL (4.8 and 4.5, respectively) and were different (P < 0.10) than their half sib families 77 (3.8 cm) and 80 (3.9 cm). Family 82 (2.5 cm) was the lowest (P < 0.10) of all families and within sire 432H was different (P < 0.10) than families 72 (3.2 cm) and 73 (3.5 cm). Gladney (2008) reported that families 76 (small family) (4.5 cm), 84 (3.8 cm), and 77 (3.4 cm), all out of sire 551G, had the longest AVTL and families 72 (2.7 cm), and 82 (small family, at the time) (2.4 cm) by sire 432H had the shortest AVTL.

Table 14. Least squares means and standard errors of teat length and diameter and udder support scores among full sibling (embryo transfer) cow families for sire of cow, family, cow age, and season of cow birth effects

Effect	AVTL[1]	AVTD[1]	USUP[1]
Sire of cow			
297J	4.0 ± 0.1[a]	2.0 ± 0.1	6.6 ± 0.1[a]
432H	3.1 ± 0.2[b]	1.8 ± 0.1	6.9 ± 0.1[bc]
437J	3.5 ± 0.2[b]	1.9 ± 0.1	6.9 ± 0.1[b]
551G	4.2 ± 0.2[a]	2.1 ± 0.1	6.7 ± 0.1[ac]
Family(sire of cow)			
70 297J	3.9 ± 0.2	2.1 ± 0.1	6.6 ± 0.1
71 297J	4.1 ± 0.2	2.0 ± 0.1	6.6 ± 0.1
72 432H	3.2 ± 0.2	2.1 ± 0.1	6.6 ± 0.1
73 432H	3.5 ± 0.5	1.6 ± 0.3	7.3 ± 0.3
82 432H	2.5 ± 0.3	1.7 ± 0.2	6.7 ± 0.2
74 437J	3.4 ± 0.4	2.0 ± 0.2	6.9 ± 0.2
75 437J	3.5 ± 0.2	1.9 ± 0.1	7.0 ± 0.1
81 437J	3.4 ± 0.2	1.9 ± 0.1	7.0 ± 0.1
83 437J	3.6 ± 0.2	1.9 ± 0.1	6.9 ± 0.1
76 551G	4.8 ± 0.5	2.2 ± 0.3	6.9 ± 0.3
77 551G	3.8 ± 0.2	2.0 ± 0.1	6.5 ± 0.1
80 551G	3.9 ± 0.2	2.1 ± 0.1	6.6 ± 0.1
84 551G	4.5 ± 0.3	2.1 ± 0.1	6.7 ± 0.2
Cow age (calf birth year)			
2 2005	3.3 ± 0.3	1.8 ± 0.2	6.9 ± 0.2
2 2006	3.1 ± 0.1	1.8 ± 0.1	7.1 ± 0.1
3 2006	3.3 ± 0.3	1.9 ± 0.2	6.9 ± 0.2
2 2007	2.8 ± 0.1	1.8 ± 0.1	6.9 ± 0.1
3 2007	3.1 ± 0.2	1.8 ± 0.1	6.8 ± 0.1
4-6 2007	3.6 ± 0.3	2.0 ± 0.2	6.5 ± 0.2
2 2008	3.3 ± 0.3	1.8 ± 0.2	7.0 ± 0.1
3 2008	3.3 ± 0.2	2.0 ± 0.1	6.7 ± 0.1
4-6 2008	3.8 ± .01	2.1 ± 0.1	6.6 ± 0.1
2 2009	4.6 ± 0.2	2.1 ± 0.1	6.5 ± 0.1
3 2009	5.1 ± .02	2.3 ± 0.1	6.5 ± 0.1
4-6 2009	5.3 ± 0.1	2.5 ± 0.1	6.2 ± 0.1
Season of cow birth			
Fall	3.9 ± 0.1[a]	2.1 ± 0.1[a]	6.7 ± 0.1
Spring	3.6 ± 0.1[b]	1.9 ± 0.1[b]	6.8 ± 0.1

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).
[1]AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score.

Cow age nested within calf birth year was significant. The trend in ET cows was as age increased so did AVTL. Gladney (2008) reported ET cows that were 4 yr old (the oldest age in his analysis) tended to have the longest AVTL. Riley et al. (2001b) found for females sired by Brahman bulls, 2 yr olds had the shortest AVTL at 3.6 cm, followed by 3 yr old cows at 4.3 cm, and 4 yr old cows had an average of 4.8 cm. For Nellore-sired females, 2 yr old females had AVTL of 3.3 cm, the 3 yr olds 4.0 cm, and 4 yr olds averaged 4.1 cm. Season of cow birth was important ($P = 0.04$) in the current study as fall born cows (3.9 cm) were longer ($P < 0.05$) than spring born cows (3.6 cm) (note the partial confounding of breed composition and actual age of the cow with season of birth).

Natural Service Cows. Sire of cow was significant. As in the ET cows, daughters of 297J (4.1 cm) and 551G (4.6) had longer ($P < 0.05$) AVTL than daughters of 432H (2.9 cm) and 437J (3.4 cm) (Table 15). This agrees with previous estimates by Gladney (2008) who reported daughters of 551G had the longest AVTL (3.9 cm), followed by 297J (3.5 cm), and 437J (3.2 cm). Cows out of sire 432H had the shortest teats with an average length of 2.8 cm, in that earlier analysis.

Cow age nested within calf birth year was significant. Unlike the ET analysis, NS cows that were 3 yr old tended to have longer AVTL than the older group in all years except 2009. Gladney (2008) reported in NS cows the breed of the cow's dam was not significant for AVTL, but stated that the half Brahman, half Hereford dams had daughters that tended to have slightly longer AVTL (3.4 cm) than did the half Brahman, half Angus dams (3.3 cm). In the preliminary analysis of current study, dam of cow nested within dam breed type was included in the model for NS cows, but was not significant.

Table 15. Least squares means and standard errors of teat length and diameter and udder support scores among half sibling (natural service) cows for sire and age of cow effects

Effect	AVTL[1]	AVTD[1]	USUP[1]
Sire of cow			
297J	4.1 ± 0.2[a]	2.3 ± 0.1[a]	6.3 ± 0.1[a]
432H	2.9 ± 0.2[b]	1.9 ± 0.1[b]	6.6 ± 0.1[b]
437J	3.4 ± 0.2[b]	1.8 ± 0.2[b]	6.9 ± 0.2[c]
551G	4.6 ± 0.4[a]	2.1 ± 0.2[ab]	6.3 ± 0.2[a]
Cow age (calf birth year)			
2 2005	3.1 ± 0.3	1.8 ± 0.2	6.9 ± 0.2
2 2006	3.0 ± 0.2	1.8 ± 0.1	6.8 ± 0.2
3 2006	3.3 ± 0.3	1.9 ± 0.2	6.6 ± 0.2
2 2007	3.8 ± 0.2	2.0 ± 0.1	6.7 ± 0.1
3 2007	3.4 ± 0.3	2.0 ± 0.2	6.6 ± 0.2
4-6 2007	3.3 ± 0.3	1.9 ± 0.2	6.5 ± 0.2
2 2008	3.7 ± 0.3	1.9 ± 0.1	6.7 ± 0.2
3 2008	4.5 ± 0.2	2.0 ± 0.1	6.5 ± 0.1
4-6 2008	4.0 ± 0.2	2.1 ± 0.1	6.4 ± 0.1
2 2009	4.1 ± 0.5	2.3 ± 0.3	6.3 ± 0.3
3 2009	5.3 ± 0.3	2.4 ± 0.2	6.0 ± 0.2
4-6 2009	5.7 ± 0.2	2.8 ± 0.1	5.8 ± 0.1

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).
[1] AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score.

Paternal Half Siblings. Sire of cow was important ($P < 0.001$). As in the other two analyses of AVTL, daughters of 297J and 551G were longest for AVTL (Table 16). Daughters of 297J (4.1 cm) and 551G (4.6) had longer ($P < 0.05$) AVTL than daughters of 432H (2.9 cm) and 437J (3.4 cm).

Cow age nested within calf birth year was significant, but no apparent trend could be seen in the least squares means (Table 16). Season of cow birth was important ($P =$ 0.09). As in the ET analysis, fall born cows (3.9 cm) were longer for AVTL than spring

Table 16. Least squares means and standard errors of teat length and diameter and udder support scores among all cows combined (paternal half sibling) for sire of cow, cow age, and season of cow birth effects

Effect	AVTL[1]	AVTD[1]	USUP[1]
Sire of cow			
297J	4.1 ± 0.2[a]	2.2 ± 0.1[a]	6.4 ± 0.1[a]
432H	2.9 ± 0.2[b]	1.9 ± 0.1[b]	6.6 ± 0.1[b]
437J	3.4 ± 0.3[b]	1.8 ± 0.1[b]	6.9 ± 0.1[c]
551G	4.6 ± 0.4[a]	2.1 ± 0.1[a]	6.5 ± 0.1[ab]
Cow age (calf birth year)			
2 2005	3.2 ± 0.2	1.9 ± 0.1	6.9 ± 0.1
2 2006	3.0 ± 0.1	1.8 ± 0.1	6.9 ± 0.1
3 2006	3.3 ± 0.2	1.9 ± 0.1	6.7 ± 0.1
2 2007	3.2 ± 0.1	1.9 ± 0.1	6.7 ± 0.1
3 2007	3.2 ± 0.1	1.9 ± 0.1	6.7 ± 0.1
4-6 2007	3.5 ± 0.2	2.0 ± 0.1	6.5 ± 0.1
2 2008	3.5 ± 0.2	1.9 ± 0.1	6.8 ± 0.1
3 2008	4.1 ± 0.1	2.0 ± 0.1	6.6 ± 0.1
4-6 2008	3.8 ± 0.1	2.1 ± 0.1	6.5 ± 0.1
2 2009	4.5 ± 0.2	2.2 ± 0.1	6.4 ± 0.1
3 2009	5.2 ± 0.2	2.4 ± 0.1	6.3 ± 0.1
4-6 2009	5.4 ± 0.1	2.6 ± 0.1	6.0 ± 0.1
Season of cow birth			
Fall	3.9 ± 0.2	2.1 ± 0.1	6.7 ± 0.1
Spring	3.7 ± 0.1	2.0 ± 0.1	6.6 ± 0.1

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).
[1] AVTL = Average teat length (cm), AVTD = Average teat diameter (cm), USUP = Udder support score.

born cows (3.7 cm) but note the partial confounding of breed composition and actual age of cow with season of birth.

Average Teat Diameter

Embryo Transfer Cows. Sire of cow was important ($P = 0.08$). Daughters of 551G (2.1 cm) had the largest AVTD and were different than daughters of 432H (1.8 cm, $P < 0.05$) and 437J (1.9 cm, $P < 0.10$). Daughters of 297J (2.0 cm) had larger ($P < 0.10$) AVTD than daughters of 432H. Family nested within sire was not significant for AVTD. Least squares means are in Table 14. Within sire 432H, family 72 (2.1 cm) had larger AVTD than half sib families 73 (1.6 cm, $P < 0.10$) and 82 (1.7 cm, $P < 0.10$).

Cow age nested within calf year of birth was also important ($P < 0.001$). In 2009, a trend could be seen where, as cow age increased, AVTD did as well (Table 14). Season of cow birth was also important ($P = 0.006$) and fall born cows had larger AVTD than spring born cows (2.1 cm versus 1.9 cm). Note that the fall born cows were about 6 mo older than the spring born cows at the time of observation.

Natural Service Cows. Sire of cow was significant. Daughters of 297J (2.3 cm) had larger ($P < 0.05$) AVTD than daughters of 432H (1.9 cm) and 437J (1.8 cm) (Table 15). These results agree with Gladney (2008). He reported cows by 297J were the largest for AVTD at 2.1 cm. Cows by 551G had AVTD of 1.9 cm, cows by 432H were 1.7 cm, and the smallest AVTD cows were by sire 437J (1.6 cm) in that earlier analysis. Cow age nested within calf year of birth was also important ($P < 0.001$), and, as was the trend in ET cows, in 2009 as cow age increased AVTD did as well.

Paternal Half Siblings. Sire of cow was significant. Daughters of 297J (2.2 cm) had larger AVTD ($P < 0.05$) than daughters of 432H (1.9 cm) and 437J (1.8 cm); daughters of 551G (2.1 cm) had larger AVTD ($P < 0.05$) than daughters of 437J. Cow age nested within calf year of birth was also important ($P < 0.001$). As in the other 2 analyses of AVTD, in 2009 a trend could be seen where, as cow age increased, AVTD did as well (Table 16). Season of cow birth was important ($P = 0.08$). Fall born cows had larger AVTD than spring born cows (2.1 cm versus 2.0 cm).

Udder Support Score

Embryo Transfer Cows. Sire of cow was significant. Daughters of 297J (6.6) had lower (looser, less desirable) USUP than daughters of 432H (6.9, $P < 0.10$) and 437J (6.9, $P < 0.05$). Daughters of 551G (6.7) had lower ($P < 0.05$) USUP than daughters of 437J. This same trend was reported by Gladney (2008) where ET cows sired by 432H and 437J had significantly higher USUP than cows sired by 297J and 551G. Family nested within sire was not significant. However there were important numerical differences among averages. Least squares means are in Table 14. Family 73 (7.3), a small family by bull 432H, had the highest USUP among all families and was different than families 72 (6.6) and 82 (6.7), also sired by 432H.

Cow age nested within calf birth year was significant. In general, as cow age increased their USUP decreased, as expected. Udder support scores tended to be the lowest in 2009. Gladney (2008) reported USUP of 7.0 for 2 and 2.5 yr old cows and 6.5 for 4 yr old cows. Season of cow birth was not significant and no apparent trends were identified.

Natural Service Cows. Sire of cow was significant, with similar ranking as in ET cows. Daughters of 297J (6.3) had lower ($P < 0.05$) USUP than daughters of 432H (6.6) and 437J (6.9); daughters of 551G (6.3) also had lower USUP that daughters of 432H (*P*

< 0.10) and 437J ($P < 0.05$). Daughters of 432H had lower ($P < 0.10$) USUP than daughters of 437J.

Cow age nested within calf birth year was significant. As was seen in ET cows and as was expected, the trend was as cows increased in age their USUP decreased. Udder support scores tended to be the lowest in 2009.

Paternal Half Siblings. Sire of cow was significant, again with the same ranking as in the other analyses. Daughters of 297J (6.4) had lower USUP than daughters of 432H (6.6, $P < 0.05$) and 437J (6.9, $P < 0.05$) and daughters of 432H had lower ($P < 0.05$) USUP than daughters of 437J. Daughters of 437J also had higher ($P < 0.05$) USUP than daughters of 551G (6.5).

Cow age nested within calf birth year was significant, with the same trend as described for the other two analyses for USUP. Season of cow birth was not significant and no apparent trends were identified.

Birth Weight

Embryo Transfer Cows. Sire of cow was not significant. Calves out of daughters by 432H (28.1 kg) tended to be lighter at birth (Table 17) than calves out of daughters by 297J (29.7), 437J (29.7 kg), and 551G (29.9 kg). Gladney (2008) reported calves out of ET daughters by sire 551G were heavier than those out of the daughters of the 3 other sires ($P < 0.10$), and that the lightest calves were from daughters of 432H (27.3 kg). The

Table 17. Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among full sibling (embryo transfer) cow families for sire of cow, family, cow age, season of cow birth, and sex of calf effects

Effect	BWT[1]	WWT[1]	PW ADG[1]
Sire of cow			
297J	29.7 ± 0.6	205.8 ± 3.6[ac]	0.97 ± 0.02[a]
432H	28.1 ± 0.9	184.4 ± 5.4[b]	0.87 ± 0.03[b]
437J	29.7 ± 0.6	199.2 ± 3.4[c]	0.97 ± 0.02[a]
551G	29.9 ± 0.8	198.1 ± 4.5[ac]	0.93 ± 0.02[a]
Family (sire of cow)			
70 297J	30.1 ± 1.9	207.3 ± 5.3	0.97 ± 0.03
71 297J	29.3 ± 1.8	204.2 ± 4.1	0.96 ± 0.02
72 432H	29.9 ± 1.8	203.2 ± 5.0	0.97 ± 0.03
73 432H	26.6 ± 2.7	175.9 ± 13.1	0.84 ± 0.07
82 432H	27.7 ± 2.3	174.2 ± 8.1	0.85 ± 0.04
74 437J	31.9 ± 2.3	213.8 ± 9.4	1.00 ± 0.05
75 437J	27.9 ± 1.8	194.8 ± 4.9	0.92 ± 0.03
81 437J	29.7 ± 1.8	200.3 ± 4.9	0.93 ± 0.03
83 437J	29.6 ± 1.8	188.1 ± 5.0	0.89 ± 0.03
76 551G	30.4 ± 3.1	205.8 ± 14.1	0.95 ± 0.07
77 551G	29.7 ± 1.8	195.8 ± 5.1	0.90 ± 0.03
80 551G	30.2 ± 1.8	193.9 ± 4.6	0.93 ± 0.02
84 551G	29.5 ± 1.9	197.0 ± 6.0	0.92 ± 0.03
Cow age (calf birth year)			
2 2005	25.7 ± 1.3	191.0 ± 5.5	0.91 ± 0.03
2 2006	28.8 ± 0.7	177.9 ± 3.3	0.86 ± 0.02
3 2006	28.9 ± 1.4	182.0 ± 5.9	0.86 ± 0.03
2 2007	30.3 ± 0.7	187.8 ± 3.2	0.90 ± 0.01
3 2007	30.7 ± 0.5	194.3 ± 3.3	0.91 ± 0.01
4-6 2007	28.5 ± 2.0	199.0 ± 5.3	0.94 ± 0.03
2 2008	28.7 ± 0.9	214.6 ± 4.4	1.02 ± 0.02
3 2008	32.2 ± 0.7	221.4 ± 3.3	1.05 ± 0.01
4-6 2008	32.2 ± 0.6	232.0 ± 3.1	1.09 ± 0.01
2 2009	29.8 ± 1.0	191.1 ± 5.0	0.92 ± 0.02
3 2009	32.3 ± 0.9	196.5 ± 4.6	0.95 ± 0.02
4-6 2009	32.2 ± 0.5	203.7 ± 2.6	0.97 ± 0.01

[a,b,c] Means in the same column without a common superscript differ ($P < 0.10$).
[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), PW ADG = Preweaning average daily gain (kg/d).

Table 17 cont.

Effect		BWT[1]	WWT[1]	PW ADG[1]
Season of cow birth				
	Fall	29.6 ± 0.6	201.9 ± 3.1[a]	0.95 ± 0.01[a]
	Spring	29.2 ± 0.5	191.8 ± 2.8[b]	0.91 ± 0.01[b]
Sex of calf				
	Female	28.3 ± 0.5[a]	191.4 ± 2.5[a]	0.91 ± 0.01[a]
	Male	30.5 ± 0.5[b]	202.4 ± 2.5[b]	0.96 ± 0.01[b]

[a,b c] Means in the same column without a common superscript differ (*P* < 0.10).

[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), PW ADG = Preweaning average daily gain (kg/d).

author attributed this to the fact that two of the families sired by 432H (73 and 82) had a small number of calves with low birth weights. Cooper et al. (2009) reported direct effects for BWT among the ET and NS cows in the current study, and their male counter parts, as calves. In general, it was consistent with the current study. In the 2009 study, ET calves by sire 432H had the lowest BWT (31.3) and calves sired by 437J had the highest BWT (34.0 kg).

Family nested within sire of cow was not significant. However there were important numerical differences among averages (Table 17). Calves out of cows belonging to the numerically small family 73 (26.6 kg) tended to be lightest at birth but were not significantly different than calves out of daughters from the other two families by 432H. Calves out of cows in the numerically small family 74 were the heaviest at birth

(31.9 kg). Within sire 437J, calves out of cows in family 74 were heavier than those from family 75 (27.9 kg).

Cow age nested within calf year of birth was significant. In 2008 and 2009, BWT tended to be higher for calves out of older cows. There is some confounding of sire breed of calf with cow age and year, because in 2009 calves out of all except the 2 yr old cows were sired by F_2 Nellore-Angus bulls, and all other calves reported in these analyses were by Angus bulls. Season of cow birth was not significant and no apparent trends were found.

Sex of calf was important ($P < 0.001$). Male calves were heavier at birth than female calves by 2.2 kg (Table 17). Gladney (2008) reported male calves weighed 1.5 kg more than female calves at birth. Cooper et al. (2009) reported ET males were heavier at birth than females (the cows in this analysis, as calves) (33.3 versus 32.7 kg).

The BWT reported in Table 17 did not include calving day nested within year as a covariate. However, from a separate analysis, the regressions of BWT on calving day within year was 0.04 kg/d ($P = 0.02$). Cooper et al. (2009) evaluated gestation length of the ET calves (the cows in the current ET analyses and their male counter parts) when they were born. Embryo transfer calves (males included) by bull 432H had the longest gestations (282.2 d) while bull 297J had the shortest gestations (279.3 d). Embryo transfer males had longer gestations (282.2 d) than females (280.0 d). The BWT analysis on ET calves by Cooper et al. (2009) did not include GL as a covariate; however, from a separate analysis, the regression of BWT on GL was 0.36 kg/d ($P < 0.001$).

Table 18. Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among half sibling (natural service) cows for sire of cow, cow age, and sex of calf effects

Effect		BWT[1]	WWT[1]	PW ADG[1]
Sire of cow				
	297J	28.4 ± 0.9	192.2 ± 4.1	0.95 ± 0.02
	432H	28.0 ± 0.7	185.4 ± 3.0	0.91 ± 0.02
	437J	27.5 ± 1.1	194.0 ± 5.4	0.97 ± 0.03
	551G	31.2 ± 1.2	193.6 ± 6.0	0.94 ± 0.04
Cow age (calf birth year)				
	2 2005	23.7 ± 1.5	175.9 ± 6.2	0.87 ± 0.04
	2 2006	27.5 ± 1.1	188.9 ± 4.8	0.93 ± 0.04
	3 2006	29.6 ± 1.6	175.1 ± 6.6	0.87 ± 0.04
	2 2007	29.8 ± 1.0	177.2 ± 4.6	0.86 ± 0.03
	3 2007	31.6 ± 1.3	194.2 ± 5.5	0.96 ± 0.03
	4-6 2007	27.5 ± 1.6	188.7 ± 6.3	0.93 ± 0.04
	2 2008	28.4 ± 1.0	204.2 ± 4.7	0.99 ± 0.03
	3 2008	30.7 ± 1.0	220.7 ± 4.4	1.08 ± 0.02
	4-6 2008	32.8 ± 1.0	230.3 ± 4.1	1.10 ± 0.02
	2 2009	28.4 ± 2.1	175.6 ± 9.4	0.83 ± 0.05
	3 2009	32.4 ± 1.1	191.4 ± 5.0	0.94 ± 0.03
	4-6 2009	34.2 ± 0.7	213.4 ± 3.3	1.07 ± 0.02
Sex of calf				
	Female	28.4 ± 0.6	186.4 ± 2.8[a]	0.91 ± 0.01[a]
	Male	29.3 ± 0.7	196.2 ± 2.9[b]	0.97 ± 0.02[b]

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).
[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), PW ADG = Preweaning average daily gain (kg/d).

Natural Service Cows. Sire of cow was marginally important ($P = 0.12$). Calves out of daughters by 551G (31.2 kg) were heavier ($P < 0.12$) at birth than calves out of daughters by 297J (28.4 kg), 432H (28.0 kg), and 437J (27.5 kg) (Table 18). Cow age nested within calf year of birth was important ($P < 0.05$). In 2008 and 2009, as cow age increased, BWT tended to increase also. There was also partial confounding of sire breed of calf with year and age of cow in the NS cows, because, in 2009, calves out of all the NS cows except the 2 yr olds were sired by F_1 Nellore-Angus bulls, and all other calves in that and other years were sired by Angus bulls. Calf sex was also important ($P = 0.12$). Male calves were heavier at birth than female calves by 0.9 kg. Gladney (2008) reported male calves weighed 1.9 kg heavier in NS cows. Cooper et al. (2009) reported NS males were also heavier at birth than females (the cows in the current analysis, as calves; 36.6 versus 35.5 kg). The BWT reported in Table 18 in the current study did not include calving day nested within year as a covariate. However, from a separate analysis, the regressions of BWT on calving day within year was 0.05 kg/d ($P = 0.004$).

Dam of cow nested within dam breed type was important ($P < 0.001$) in the model during preliminary analysis of the current study, but not included in the final model. Cooper et al. (2009) included dam breed type and dam nested within dam breed type in the model when evaluating direct effects of BWT in NS calves. Neither were significant ($P > 0.10$). Gladney (2008) reported that breed of the cow's dam affected ($P = 0.064$) BWT of calves from NS cows. In that earlier analysis, calves out of cows whose dams were half Brahman, half Hereford were 2.0 kg heavier at birth (28.4 kg) than those out of cows that were half Brahman, half Angus (26.4 kg). Bailey et al. (1988) reported somewhat similar results where calves out of Brahman-Hereford F_1 dams had birth weights of 33.5 kg, which was 2.7 kg more than calves out of Brahman-Angus F_1 dams (30.8 kg).

Table 19. Least squares means and standard errors of birth weight, weaning weight, and preweaning average daily gain in calves among all cows combined (paternal half siblings) for sire of cow, cow age, season of cow birth, and sex of calf effects

Effect		BWT[1]	WWT[1]	PW ADG[1]
Sire of cow				
	297J	29.1 ± 0.6	201.9 ± 11.5[a]	0.97 ± 0.02
	432H	28.7 ± 0.5	192.4 ± 11.4[b]	0.92 ± 0.01
	437J	28.8 ± 0.6	193.5 ± 11.4[b]	0.93 ± 0.01
	551G	30.2 ± 0.6	194.2 ± 11.2[b]	0.93 ± 0.01
Cow age (calf birth year)				
	2 2005	25.1 ± 1.0	185.5 ± 4.1	0.89 ± 0.02
	2 2006	28.4 ± 0.6	182.6 ± 2.8	0.88 ± 0.01
	3 2006	29.3 ± 1.1	180.8 ± 4.5	0.86 ± 0.02
	2 2007	29.8 ± 0.6	184.0 ± 2.6	0.88 ± 0.01
	3 2007	31.1 ± 0.6	195.6 ± 2.8	0.94 ± 0.01
	4-6 2007	28.2 ± 1.0	196.2 ± 4.1	0.94 ± 0.02
	2 2008	28.4 ± 0.7	210.2 ± 3.2	1.01 ± 0.04
	3 2008	31.4 ± 0.6	220.6 ± 2.5	1.05 ± 0.01
	4-6 2008	32.5 ± 0.6	232.8 ± 2.5	1.11 ± 0.01
	2 2009	29.6 ± 0.9	190.3 ± 4.3	0.92 ± 0.02
	3 2009	32.1 ± 0.7	193.7 ± 3.4	0.95 ± 0.02
	4-6 2009	32.9 ± 0.4	207.6 ± 2.1	1.01 ± 0.01
Season of cow birth				
	Fall	29.3 ± 0.6	198.1 ± 2.8	0.95 ± 0.01
	Spring	29.1 ± 0.4	193.0 ± 1.7	0.93 ± 0.01
Sex of calf				
	Female	28.3 ± 0.4[a]	190.0 ± 1.9[a]	0.91 ± 0.01[a]
	Male	30.1 ± 0.4[b]	201.0 ± 1.9[b]	0.97 ± 0.01[b]

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).
[1] BWT = Birth weight of calf (kg), WWT = Weaning weight of calf (kg), PW ADG = Preweaning average daily gain (kg/d).

Paternal Half Sibs. Sire of cow was not significant. However there were important numerical differences among averages. Calves out of daughters by 551G (30.2 kg) were heavier than calves out of daughters by 432H (28.7 kg) and 437J (28.8 kg), and tended to be heavier than those out of daughters by 297J (29.1 kg) (Table 19).

Season of cow birth was not significant. Cow age nested within calf year of birth was significant ($P < 0.05$). In 2008 and 2009, as cow age increased, BWT tended to increase also. As discussed for the other 2 analyses for BWT, there is some partial confounding of sire breed of calf with year and age of the cow. Sex of calf was important ($P < 0.001$). Male calves were heavier at birth than female calves by 1.8 kg.

Weaning Weight

Embryo Transfer Cows. Sire of cow affected WWT ($P < 0.01$). In ET cows, calves out of daughters of 297J (205.8 kg) were heavier than calves out of daughters by 432H (184.4 kg, $P < 0.05$), 437J (199.2 kg, $P = 0.15$), and 551G (198.1 kg, $P = 0.16$). Calves out of daughters by 437J were heavier ($P < 0.05$) than those by 432H. Gladney (2008) reported similar results. In his analysis at the earlier stage of this study, calves out of daughters by 432H (175.7 kg) were the lightest and those out of daughters of 297J (209.1 kg) were the heaviest at weaning. In that earlier analysis, calves out of daughters of 297J were significantly different from those out of daughters of 432H and 437J. Cooper et al. (2009) also found similar results, as direct effects in ET calves where those by 432H had the lowest WWT (213.8 kg) and those by bull 297J had the heaviest WWT (225.0 kg).

Family nested within sire of cow also affected WWT in ET cows ($P < 0.05$). Calves out of cows from the numerically small families 73 (175.9 kg) and 82 (174.2 kg), which were both sired by 432H, were the lightest at weaning. It is important to note that families 73 and 82 had 7 and 14 total born calves, respectively. Calves out of cows from family 73 were lighter ($P < 0.10$) than those from family 72 (203.2 kg), also by sire

432H. Calves out of cows from family 74 (213.8 kg) were heaviest of all families and heavier than families 75 (194.8 kg, $P < 0.10$) and 83 (188.1 kg, $P < 0.05$), all three of which were sired by 437J.

Gladney (2008) reported similar results. The two numerically small families from sire 432H (82 at 150.5 kg and 73 at 174.6 kg) were the lightest at weaning of all the families, but these families only had 2 calves in each in that stage of this study. The numerically small family 74 produced by sire 437J had the heaviest calves at weaning for all families at 215.1 kg in his analysis.

Calves out of fall born (201.9 kg) cows were heavier ($P < 0.01$) than those out of spring born cows (191.8 kg). It is important to note than all fall born cows were allowed to calve at either 2 or 2.5 yr of age, and that the WWT of the fall born calves (when the dams were 2 yr of age) were not included in the analyses. Also, as analyzed, the fall born cows, that were designated as a given age, were actually about 6 mo older than the spring born cows that were designated as the same age.

Cow age nested within calf year of birth also affected WWT in the ET cows ($P < 0.001$). In general, as cow age increased so did WWT of the calves. As noted in the BWT discussion, there was some partial confounding of sire breed of calf with year and age of the cow. Weaning weights tended to be higher in 2008. Sex of calf was also important ($P < 0.001$). Male calves were heavier than female calves at weaning by 11.0 kg. Gladney (2008) found steer calves were 6.7 kg heavier than heifer calves. Cooper et al. (2009) reported ET F_2 Nellore-Angus males were heavier at weaning (225.2 kg) than females (211.2 kg).

The regression on weaning age was important (P < 0.001). The regression of WWT on weaning age of calf was 0.82 ± 0.07 kg/d. Gladney (2008) reported a coefficient of 0.85 ± 0.09 kg/d. Cooper et al. (2009) reported the regression of WWT on weaning age was 0.88 kg/d (P < 0.001) in ET F_2 Nellore-Angus calves.

Natural Service Cows. Sire of cow was not important (P = 0.24). In NS cows, calves out of daughters of 432H (185.4 kg) tended to be lighter (P < 0.24) than those out of daughters of 297J (192.2 kg) and 437J (194.0 kg). Cooper et al. (2009) reported NS calves by 432H (i.e., the cows in this analysis and their steer counter-parts) had the lowest WWT (223.6 kg) and those by 297J had the heaviest WWT (243.5 kg).

Cow age nested within calf year of birth was important (P < 0.001). In general, as cow age increased so did WWT. Weaning weights tended to be higher in 2008. Sex of calf was important (P < 0.001). Male calves were heavier than female calves at weaning by 9.8 kg for calves out of NS cows. Gladney (2008) found similar results, as male calves were 15.9 kg heavier than female calves. Cooper et al. (2009) reported NS steers were heavier at weaning (241.9 kg) than heifers (225.7 kg).

The regression on weaning age was important (P < 0.001). The regression of WWT on weaning age of calf was 0.71 ± 0.08 kg/d in calves out of NS cows. Gladney (2008) reported coefficients of 0.77 ± 0.13 kg/d and Cooper et al. (2009) reported a regression coefficient of 0.93 kg/d (P < 0.001) in the ET F_2 calves.

Dam of NS cow nested within dam breed type was included in preliminary analysis but was not significant. Cooper et al. (2009) included dam nested within dam breed type (P < 0.001) in the analysis of WWT among NS calves. Gladney (2008) included breed of cow's dam in the model for NS cows, but it was not significant. However, those cows whose dam's breed was half Brahman and half Angus did tend to have calves with heavier weaning weights (199.0 kg) than the calves out of cows with dams that were half Brahman, half Hereford (191.5 kg). In contrast, Bailey et al. (1988) found that calves from Brahman-Hereford dams weighed 213.6 kg at weaning, compared to 204.2 kg for calves out of Brahman-Angus dams. Sanders et al. (2005) evaluated similar calves, Brahman/Angus/Nellore/Hereford, and found that calves out of Brahman-Hereford F_1 cows weighed 239.1 kg at weaning compared to calves out of Brahman-Hereford F_2 cows that weighed 220.6 kg.

Paternal Half Siblings. Sire of cow was important ($P < 0.05$) in this analysis. Calves out of daughters by 297J (201.9 kg) were heavier ($P < 0.05$) than those out of daughters by 432H (192.4 kg), 437J (193.5 kg), and 551G (194.2 kg).

Season of cow birth was important ($P < 0.10$). Calves out of fall born (198.1 kg) cows were heavier than those out of spring born cows (193.0 kg). As in ET analysis, it is important to note than all fall born cows were allowed to calve at either 2 or 2.5 yr of age, and that the WWT of the fall born calves (when the dams were 2 yr of age) were not included in the analyses. Also, as analyzed, the fall born cows, that were designated as a given age, were actually about 6 mo older than the spring born cows that were designated as the same age.

Cow age nested within calf year of birth was important ($P < 0.001$). In general, as cow age increased so did WWT. Weaning weights tended to be higher in 2008. Sex of calf was important ($P < 0.001$). As expected, male calves were heavier than female calves at weaning (11.0 kg). The regression on weaning age was important (*P* < 0.001). The regression coefficient of WWT on weaning age of calf was 0.78 ± 0.05.

Preweaning Average Daily Gain

Embryo Transfer Cows. Sire of cow was important (*P* < 0.05). Calves out of daughters by 432H (0.87 kg/d) had lower (*P* < 0.05) ADG than those out of cows by 297J (0.97 kg/d), 437J (0.97 kg/d), and 551G (0.93 kg/d). Gladney (2008) reported calves out of ET cows sired by 297J ranked the highest for average daily gain at 0.83 kg/d; calves from cows sired by 432H (0.69 kg/d) had lower (*P* < 0.10) ADG than calves from cows out of the other 3 sires. As with BWT and WWT, the 2 numerically small families (73 and 82) had a large effect on this least squares mean. Calves from cows sired by 551G and 437J had similar average daily gains at 0.78 kg/d in that earlier analysis when the cows were younger.

Family nested within sire of cow was important in the ET analysis of PW ADG (*P* = 0.03). Least squares means are in Table 17. Within sire 432H, calves out of cows from the numerically small families 73 (0.84 kg/d) and 82 (0.85 kg/d) had the lowest PW ADG and were different (*P* < 0.10) than family 72. Among families within sire 437J, calves out of cows from family 74 (1.00 kg/d) had higher PW ADG than families 75 (0.92 kg/d, *P* < 0.10) and 83 (0.89 kg/d, P < 0.05). Gladney (2008) reported that calves out of cows in families 74 (437J) and 70 (297J) ranked the highest for ADG at 0.86 and 0.85 kg/d among ET families; calves from family 82 (432H) ranked the lowest (only 2 calves in this family in his analysis) for average daily gain at 0.58 kg/d.

Cow age nested within calf year of birth was significant ($P < 0.001$). In general, as cow age increased so did PW ADG. In 2008 calves tended to have higher PW ADG than other years. Season of cow birth was significant in ET cows. Cows born in the fall raised calves that had higher ($P < 0.05$) PW ADG than spring born cows, but note the comments regarding season of cow birth in the discussion of WWT. Sex of calf was important ($P < 0.001$). Male calves had heavier PW ADG than female calves (0.96 versus 0.91 kg/d). Gladney (2008) reported male calves (0.78 kg/d) averaged 0.02 kg/d more gain than female calves (0.76 kg/d) in ET families ($P < .10$) in that earlier analysis.

Natural Service Cows. Sire was not important ($P = 0.20$); however, there were important numerical differences among averages. Calves out of daughters by 437J (0.97 kg/d) had higher ADG ($P < 0.20$) than those out of cows by 432H (0.91 kg/d). Calves out of daughters by 297J (0.95 kg/d) tended ($P < 0.20$) to have higher ADG than those out of daughters of 432H.

Cow age nested within calf year of birth was important ($P < 0.001$). In general, as cow age increased so did PW ADG (Table 18). In 2008 calves tended to have higher PW ADG than other years. Sex of calf was important ($P < 0.001$). Male calves had heavier PW ADG than female calves (0.97 versus 0.91 kg/d). Gladney (2008) reported male calves had ADG of 0.83 kg/d and female calves averaged 0.76 kg/d in that earlier analysis.

Paternal Half Siblings. Sire was important ($P < 0.10$). In PHS, calves out of daughters by 297J (0.97 kg/d) had higher ADG than those out of daughters by 432H (0.92 kg/d, $P < 0.10$), 437J (0.93 kg/d, $P < 0.10$), and 551G (0.93 kg/d, $P < 0.10$).

Cow age nested within calf year of birth was important ($P < 0.001$). In general, as cow age increased so did PW ADG (Table 19). In 2008 calves tended to have higher PW ADG than other years. Unlike the ET analysis of PW ADG, season of cow birth was not important in PHS analysis ($P = 0.23$). Sex of calf was important ($P < 0.001$). Male calves had heavier PW ADG than female calves (0.97 versus 0.91 kg/d).

Cow Body Condition Score

Embryo Transfer Cows. Sire was not significant. Daughters of 437J (5.57) had slightly higher ($P < 0.25$) BCS than daughters of 551G (5.40). Sire 432H (5.51) ranked second followed by 297J (5.48). Within sire 551G, family 76 is numerically small and had a large effect on this least squares mean. Also note that family 84 by 551G had the highest adjusted mean of any family. Family nested within sire of cow was not a significant factor affecting cow BCS. However there were important numerical differences among averages. Least squares means are shown in the table on page 68. Cows out of families 84 (5.61), 74, and 83 (both 5.58) were the highest and cows out of the small family 76 (4.96) were the lowest. For families within 551G, 76 was lower ($P < 0.05$) than 77(5.49), 80 (5.55), and 84.

Cow age nested within calf year of birth was significant. No apparent trend can be seen except in 2007 when, as cow age increased, so did BCS. Season of cow birth was important ($P = 0.03$). Cows born in the fall were in heavier condition at weaning than those born in the spring. It is important to note that fall born cows were allowed to calve at 2.5 yr of age compared to the spring born cows that were 2 yr of age at calving. Also, as analyzed, the fall born cows, that were designated as a given age, were actually about

6 mo older than the spring born cows that were designated as the same age. Calving record was not significant for any of the analyses. Lactation was significant. Cows that were not lactating as of July 1 were in heavier condition at the time that the calves on the lactating cows were weaned by 0.60 units of BCS.

Natural Service Cows. Sire affected BCS in NS cows (P = 0.10). As shown in the table on page 70, daughters of 473J (5.60) had higher (P = 0.15) BCS than daughters of 551G (5.38). Daughters of bulls 297J and 432H both had adjusted means of 5.47.

Cow age nested within calf year of birth was significant. No apparent trend can be seen except in 2007 when older cows had higher BCS. Calving record was not significant for any of the analyses. Lactation was significant. Cows that were not lactating as of July 1 were in heavier condition at the time of weaning of the other cows' calves by 0.56 units of BCS.

Paternal Half Siblings. Sire was not significant in PHS. No statistical differences were detected in PHS analysis, however, the mean for daughters of 437J (5.56) was numerically the highest. Cow age nested within calf year of birth was significant. No apparent trend can be seen except in 2007 when older cows had higher BCS. Season of cow birth was important in PHS (P = 0.11). As shown in the table on page 71, cows born in the fall were in heavier condition at weaning than those born in the spring. It is important to note that fall born cows were allowed to calve at 2.5 yr of age compared to the spring born cows that were 2 yr of age at calving, and the actual age of the fall born cows was about 6 mo older than the spring born cows at the time of scoring. Calving record was not significant for any of the analyses. Lactation was significant. Cows that were not lactating as of July 1 were in heavier condition at the time of weaning of the other cows' calves by 0.53 units of BCS.

Calf Body Condition Score

Embryo Transfer Cows. Sire of cow was not significant. Calves out of daughters by 432H (5.23) had slightly less condition at weaning than those out of daughters of 297J (5.34), 437J (5.30), and 551G (5.30). Note that these means for calf BCS correspond almost exactly with the adjusted means for weaning weight. Family nested within sire of cow appeared to have an effect ($P = 0.14$). Least squares means are in Table 20. Calves out of cows from families 74 (5.46) and 80 (5.43) were the heaviest conditioned and those out of cows from family 76 (5.14) were the lightest conditioned. For families within sire 437J, calves out of cows from family 74 were heavier conditioned ($P < 0.14$) than those out of cows from families 75 (5.23), 81 (5.23), and 83 (5.28). For families within sire 551G, calves out of cows from family 80 were heavier conditioned ($P < 0.14$) than those out of cows from family 84 (5.28).

Cow age within calf year of birth was important ($P < 0.001$). Cows 4 yr of age and older tended to wean calves in heavier condition than younger cows. Season of cow birth was not important ($P = 0.24$). Sex of calf may have had a minor effect ($P = 0.15$). Male calves tended to be heavier conditioned at weaning than females by 0.04 units (Table 20).

Natural Service Cows. Sire of cow was not significant. In NS cows, there was some tendency for calves out of daughters of 297J to be in the heavier condition (5.29) at weaning than those out of the other groups of cows. Cow age within calf year of birth

Table 20. Least squares means and standard errors of cow body condition score, calf body condition score, and cow weight among full sibling (embryo transfer) cow families for sire of cow, family, cow age, season of cow birth, sex of calf, calving record, and lactation status effects

Effect	Cow BCS[1]	Calf BCS[1]	CW[1]
Sire of cow			
297J	5.48 ± 0.06	5.34 ± 0.04	457.1 ± 7.2
432H	5.51 ± 0.08	5.23 ± 0.06	472.8 ± 11.5
437J	5.57 ± 0.07	5.30 ± 0.05	467.8 ± 7.2
551G	5.40 ± 0.07	5.30 ± 0.05	456.1 ± 8.6
Family(sire of cow)			
70 297J	5.46 ± 0.08	5.31 ± 0.06	447.2 ± 10.8
71 297J	5.50 ± 0.07	5.37 ± 0.05	466.7 ± 8.40
72 432H	5.53 ± 0.07	5.22 ± 0.05	441.1 ± 10.0
73 432H	5.47 ± 0.17	5.23 ± 0.13	500.0 ± 28.3
82 432H	5.53 ± 0.13	5.24 ± 0.09	477.3 ± 17.5
74 437J	5.58 ± 0.12	5.46 ± 0.08	461.8 ± 20.5
75 437J	5.53 ± 0.07	5.23 ± 0.05	468.2 ± 10.1
81 437J	5.51 ± 0.08	5.23 ± 0.05	458.1 ± 9.70
83 437J	5.58 ± 0.08	5.28 ± 0.06	480.0 ± 10.0
76 551G	4.96 ± 0.20	5.14 ± 0.14	435.4 ± 29.0
77 551G	5.49 ± 0.08	5.35 ± 0.05	448.5 ± 10.0
80 551G	5.55 ± 0.07	5.43 ± 0.05	484.3 ± 9.10
84 551G	5.61 ± 0.10	5.28 ± 0.08	456.4 ± 11.9
Cow age (calf birth year)			
2 2005	5.33 ± 0.14	4.99 ± 0.09	446.3 ± 8.6
2 2006	5.34 ± 0.05	5.00 ± 0.05	428.7 ± 5.9
3 2006	5.15 ± 0.14	4.90 ± 0.10	459.5 ± 8.6
2 2007	5.43 ± 0.07	5.00 ± 0.05	441.3 ± 6.0
3 2007	5.67 ± 0.07	5.02 ± 0.05	482 9 ± 5.9
4-6 2007	6.04 ± 0.14	5.41 ± 0.09	510.4 ± 8.7
2 2008	5.45 ± 0.08	5.34 ± 0.06	428.0 ± 7.8
3 2008	5.48 ± 0.07	5.33 ± 0.05	487.6 ± 5.9
4-6 2008	5.65 ± 0.07	5.63 ± 0.04	512.5 ± 5.8
2 2009	5.62 ± 0.08	5.92 ± 0.07	432.2 ± 8.6
3 2009	5.50 ± 0.08	5.91 ± 0.06	466.1 ± 7.7
4-6 2009	5.70 ± 0.05	5.98 ± 0.04	517.5 ± 5.2

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).
[1] Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg).

Table 20 cont.

Effect		Cow BCS[1]	Calf BCS[1]	CW[1]
Season of cow birth				
	Fall	5.5 ± 0.06[a]	5.31 ± 0.04	471.8 ± 6.5[a]
	Spring	5.4 ± 0.05[b]	5.28 ± 0.03	456.1 ± 5.9[b]
Sex of calf				
	Female		5.28 ± 0.03	
	Male		5.32 ± 0.03	
Calving record				
	Yes	5.49 ± 0.05		463.1 ± 5.5
	No	5.48 ± 0.05		463.5 ± 5.5
Lactation Status				
	Yes	5.2 ± 0.04[a]		433.4 ± 5.1[a]
	No	5.8 ± 0.06[b]		494.6 ± 5.6[b]

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).

[1] Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg).

was important ($P < 0.001$). Cows that were 4 yr of age and older tended to wean calves in heavier condition than younger cows except in 2008 where 3 yr old cows weaned calves in heavier condition. Sex of calf was not important in NS cows ($P = 0.66$), but male calves tended to be heavier conditioned at weaning than females by 0.02 units of BCS (Table 21).

Paternal Half Siblings. Sire of cow was not significant. However there were important numerical differences among averages. Calves out of daughters of 297J (5.34) were in heavier condition at weaning than those out of daughters by 437J (5.23), which is consistent with the weaning weight adjusted means for these 2 groups of calves.

Table 21. Least squares means and standard errors of cow body condition score, calf body condition score, and cow weight among half sibling (natural service) cows for sire of cow, cow age, sex of calf, calving record, and lactation status effects

Effect		Cow BCS[1]	Calf BCS[1]	CW[1]
Sire of cow				
	297J	5.47 ± 0.08	5.29 ± 0.07	460.4 ± 9.2
	432H	5.47 ± 0.06	5.19 ± 0.05	454.0 ± 7.0
	437J	5.60 ± 0.10	5.18 ± 0.09	464.8 ± 16.1
	551G	5.38 ± 0.11	5.18 ± 0.08	451.3 ± 16.1
Cow age (calf birth year)				
	2 2005	5.26 ± 0.14	5.01 ± 0.13	432.8 ± 11.4
	2 2006	5.60 ± 0.11	4.98 ± 0.10	429.0 ± 9.2
	3 2006	5.11 ± 0.15	5.01 ± 0.14	452.8 ± 11.1
	2 2007	5.32 ± 0.09	5.01 ± 0.09	449.6 ± 8.4
	3 2007	5.40 ± 0.11	4.98 ± 0.12	486.0 ± 9.3
	4-6 2007	6.07 ± 0.15	5.20 ± 0.13	510.2 ± 11.1
	2 2008	5.55 ± 0.08	5.49 ± 0.09	423.6 ± 9.0
	3 2008	5.49 ± 0.09	5.62 ± 0.08	500.0 ± 8.6
	4-6 2008	5.67 ± 0.09	5.43 ± 0.08	519.8 ± 8.5
	2 2009	5.68 ± 0.14	5.19 ± 0.18	418.9 ± 15.3
	3 2009	5.55 ± 0.09	5.44 ± 0.09	440.5 ± 9.2
	4-6 2009	5.58 ± 0.07	5.77 ± 0.06	494.7 ± 7.6
Sex of calf				
	Female		5.20 ± 0.05	
	Male		5.22 ± 0.05	
Calving record				
	Yes	5.52 ± 0.06		450.6 ± 6.9
	No	5.43 ± 0.07		464.7 ± 8.6
Lactation status				
	Yes	5.20 ± 0.06[a]		425.3 ± 6.4[a]
	No	5.76 ± 0.08[b]		489.9 ± 7.2[b]

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).

[1] Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg).

Table 22. Least squares means and standard errors of cow body condition score, calf body condition score, and cow weight among all cows combined (paternal half sibling) for sire of cow, cow age, sex of calf, calving record, and lactation status effects

Effect		Cow BCS[1]	Calf BCS[1]	CW[1]
Sire of cow				
	297J	5.50 ± 0.05	5.34 ± 0.05	467.4 ± 7.5
	432H	5.50 ± 0.05	5.27 ± 0.04	462.6 ± 6.3
	437J	5.56 ± 0.05	5.23 ± 0.05	469.8 ± 7.3
	551G	5.51 ± 0.05	5.29 ± 0.05	458.6 ± 8.0
Cow age (calf birth year)				
	2 2005	5.35 ± 0.10	5.03 ± 0.08	443.6 ± 7.3
	2 2006	5.42 ± 0.06	5.00 ± 0.05	431.5 ± 5.6
	3 2006	5.19 ± 0.10	4.98 ± 0.09	460.0 ± 7.4
	2 2007	5.42 ± 0.05	5.01 ± 0.05	448.4 ± 5.4
	3 2007	5.59 ± 0.06	5.01 ± 0.05	486.6 ± 5.6
	4-6 2007	6.11 ± 0.10	5.34 ± 0.08	514.2 ± 7.5
	2 2008	5.54 ± 0.06	5.41 ± 0.06	432.1 ± 5.9
	3 2008	5.52 ± 0.05	5.45 ± 0.05	496.0 ± 5.4
	4-6 2008	5.67 ± 0.06	5.57 ± 0.05	518.3 ± 5.4
	2 2009	5.68 ± 0.07	5.76 ± 0.07	432.5 ± 7.6
	3 2009	5.56 ± 0.06	5.70 ± 0.06	459.5 ± 5.9
	4-6 2009	5.59 ± 0.04	5.91 ± 0.04	512.6 ± 4.9
Season of cow birth				
	Fall	5.55 ± 0.05	5.31 ± 0.04	474.4 ± 6.7[a]
	Spring	5.48 ± 0.03	5.25 ± 0.03	454.7 ± 4.0[b]
Calving Record				
	Yes	5.54 ± 0.04		462.7 ± 4.8
	No	5.49 ± 0.04		466.4 ± 5.6
Lactation Status				
	Yes	5.25 ± 0.03[a]		432.4 ± 4.5[a]
	No	5.78 ± 0.05[b]		496.7 ± 4.9[b]
Sex of calf				
	Female		5.26 ± 0.03	
	Male		5.30 ± 0.03	

[a,b] Means in the same column without a common superscript differ ($P < 0.10$).

[1] Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight (kg).

Cow age within calf year of birth was important ($P < 0.001$). As in ET cows, PHS cows 4 yr of age and older tended to wean calves in heavier condition than younger cows. Season of cow birth affected calf BCS in PHS analysis ($P = 0.08$). Calves from fall born cows were in heavier condition at weaning than those from spring born cows (Table 22). As commented in the WWT section, all fall born cows were allowed to calve at either 2 or 2.5 yr of age, and that the BCSs of the fall born calves (when the dams were 2 yr of age) were not included in the analyses. Also, as analyzed, the fall born cows, that were designated as a given age, were actually about 6 mo older than the spring born cows that were designated as the same age. Sex of calf was not significant for calf BCS. Male calves tended to be heavier conditioned at weaning than females by 0.04 units of BCS (Table 22).

Cow Weight

Embryo Transfer Cows. Sire of cow was not significant. ET daughters of 432H and 437J tended to be heavier than daughters of other sires. Daughters of 551G tended to be the lightest. Gladney (2008) found the same trends for ET cows. Family nested within sire of cow was important ($P = 0.02$). Least squares means are in Table 20. Cows in the numerically small family 73 were the heaviest (500.0 kg) and those in family 76 (also numerically small) were the lightest (435.4 kg). Within sire 432H, cows from family 72 (441.1 kg) were lighter ($P < 0.10$) than those from families 73 and 82 (477.3 kg). Within sire 437J, cows from family 81 (458.1 kg) were lighter ($P < 0.10$) than those from family 83 (480.0 kg). Within sire 551G, cows from family 80 (484.3 kg) were heavier than those from family 77 (448.5 kg, $P < 0.05$), 76 ($P = 0.11$), and 84 (456.4 kg, $P < 0.10$). Gladney

(2008) reported families 83 and 80 ranked the heaviest for CW at 494.3 and 485.3 kg, respectively; note that, except for the numerically small family 73, these 2 families had the highest adjusted means in the current analysis. The ET families that ranked the lightest for CW were 76 (small family) (551G) and 70 (297J) at 409.6 and 423.5 kg, respectively, in that earlier analysis.

Season of cow birth was important ($P = 0.02$). Fall born cows were heavier than spring born cows by 15.7 kg (Table 20). As noted in the section on cow BCS, the fall born cows, that were designated as a given age, were actually about 6 mo older than the spring born cows that were designated as the same age. Calving record ($P = 0.96$) was not important in the ET analysis. Lactation status was important ($P < 0.001$). Cows that were lactating as of July 1 were lighter at the time that calves were weaned by 61.2 kg (Table 20). Riley et al. (2001a) also found lactation status to be significant for CW.

Natural Service Cows. Sire of cow was not important ($P = 0.78$). Daughters of 437J tended to be the heaviest (464.8 kg) followed by 297J (460.4 kg), 432H (454.0 kg), and 551G (451.3 kg).

Calving record affected CW in NS cows ($P = 0.12$). Natural service cows that failed to wean a calf in at least one year (464.7 kg) were heavier than those that had a perfect record (450.6 kg), as defined earlier (Table 21). Lactation status was important ($P < 0.001$). Cows that were lactating as of July 1 were lighter at the time the calves were weaned by 64.6kg.

Paternal Half Siblings. Sire of cow was not significant. Daughters of 551G tended to be the lightest. Season of cow birth was important ($P = 0.002$). Fall born cows were heavier than spring born cows by 19.7 kg (Table 22). Again, as noted in the section on cow BCS, the fall born cows, that were designated as a given age, were actually about 6 mo older than the spring born cows that were designated as the same age. Calving record was not important. Lactation status was important ($P < 0.001$). Cows that were lactating as of July 1 were lighter at the time the calves were weaned by 64.3 kg (Table 22).

Correlations

Correlations were calculated for traits CR, WR, DISP, AVTL, AVTD, USUP, BWT, WWT, and PW ADG, cow BCS at weaning, calf BCS at weaning, and CW. Pearson correlation coefficients for traits measured in ET, NS, and PHS cows are shown in the tables on pages 75, 76, and 77, respectively.

The correlation coefficients ($P < 0.001$) between CR and WR were 0.78 (Table 23), 0.84 (Table 24), and 0.80 (Table 25) for ET, NS, and PHS, respectively. Calving rate was negatively correlated ($P < 0.001$) with cow BCS in all analyses (range -0.27 to -0.31) and with CW in ET and PHS (range -0.25 to -0.26). WR was also negatively correlated ($P < 0.001$) with cow BCS (range -0.34 to -0.38) and CW (range -0.31 to -0.33) in all analyses. This suggests that cows that did not have or wean a calf tended to put on more flesh and weight than those that did. Weaning rate was also correlated with AVTL (-0.13, $P < 0.05$), AVTD (-0.24, $P < 0.001$), and USUP (0.12, $P < 0.05$) in ET cows, DISP (-0.16, $P < 0.05$) in NS cows, and AVTD (-0.16, $P < 0.001$) in PHS cows.

Birth weight was correlated ($P < 0.001$) to WWT (range 0.33 to 0.38) and PW ADG (range 0.52 to 0.55) in all analyses. Birth weight in calves out of ET cows was

Table 23. Pearson correlation coefficients and *P*-values among traits measured in full sibling (embryo transfer) cow families

	Trait[1]											
Trait	CR	WR	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW	AVTL	AVTD	USUP	DISP
CR	1	0.78**	.	.	.	-0.29**	.	-0.25**	.	.	.	.
WR		1	-0.02	.	.	-0.38**	.	-0.33**	-0.13*	-0.24**	0.12*	0.03
BWT			1	0.38**	0.52**	0.10*	0.24**	0.28**	0.21**	0.18**	-0.27**	0.07
WWT				1	0.81**	0.02	0.20**	0.25**	0.02	0.08	-0.15*	0.04
PW ADG					1	0.06	0.32**	0.27**	0.20**	0.23**	-0.28**	-0.01
Cow BCS						1	0.15*	0.41**	0.13*	0.17**	-0.11*	0.02
Calf BCS							1	0.39**	0.56**	0.40**	-0.32**	0.01
CW								1	0.27**	0.32**	-0.25**	0.04
AVTL									1	0.63**	-0.39**	-0.05
AVTD										1	-0.53**	-0.06
USUP											1	0
DISP												1

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning average daily gain, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition.
* = $P \leq 0.05$, ** = $P \leq 0.001$.

Table 24. Pearson correlation coefficients and *P*-values among traits measured in half sibling (natural service) cow families

	Trait[1]											
Trait	CR	WR	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW	AVTL	AVTD	USUP	DISP
CR	1	0.84**	.	.	.	-0.27**	.	.	.	.	.	.
WR		1	-0.11	.	.	-0.34**	.	-0.31**	0.02	-0.04	-0.01	-0.16*
BWT			1	0.33**	0.55**	0.00	0.25**	0.28**	0.32**	0.29**	-0.33**	0.07
WWT				1	0.71**	-0.01	0.37**	0.29**	0.06	0.05	-0.11	0.04
PW ADG					1	0.04	0.42**	0.34**	0.29**	0.27**	-0.32**	0.07
Cow BCS						1	0.01	0.33**	0.12*	0.04	0.00	-0.02
Calf BCS							1	0.15*	0.17*	0.16*	-0.24**	0.11
CW								1	0.29**	0.23**	-0.17*	0.00
AVTL									1	0.67**	-0.49**	0.11
AVTD										1	-0.60**	0.06
USUP											1	-0.06
DISP												1

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning average daily gain, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition.
* = $P \leq 0.05$, ** = $P \leq 0.001$.

Table 25. Pearson correlation coefficients and *P*-values among traits measured in all cows combined (paternal half siblings)

	Trait[1]											
Trait	CR	WR	BWT	WWT	PW ADG	Cow BCS	Calf BCS	CW	AVTL	AVTD	USUP	DISP
CR	1	0.80**	.	.	.	-0.31**	.	-0.26**	.	.	.	.
WR		1	-0.05	.	.	-0.37**	.	-0.32**	-0.07	-0.16**	0.06	-0.03
BWT			1	0.36**	0.53**	0.06	0.25**	0.28**	0.25**	0.22**	-0.29**	0.08*
WWT				1	0.77**	0.00	0.27**	0.27**	0.04	0.06	-0.12**	0.05
PW ADG					1	0.04	0.36**	0.29**	0.24**	0.25**	-0.30**	0.02
Cow BCS						1	0.10*	0.38**	0.13**	0.11*	-0.06	0.01
Calf BCS							1	0.30**	0.40**	0.29**	-0.27**	0.06
CW								1	0.27**	0.27**	-0.20**	0.03
AVTL									1	0.65**	-0.43**	0.01
AVTD										1	-0.57**	-0.03
USUP											1	0.00
DISP												1

[1] CR = Calving rate, WR = Weaning rate, BWT = Birth weight, WWT = Weaning weight, PW ADG = Preweaning average daily gain, Cow BCS = Cow body condition score, Calf BCS = Calf body condition score, CW = Cow weight, AVTL = Average teat length, AVTD = Average teat diameter, USUP = Udder support score, DISP = Disposition.
* = $P \leq 0.05$, ** = $P \leq 0.001$.

correlated ($P < 0.05$) with cow BCS (0.10) but not correlated in NS or PHS. In all analyses, BWT was correlated ($P < 0.001$) with calf BCS (range 0.24 to 0.25), CW (0.28), AVTL (range 0.21 to 0.32), AVTD (range 0.18 to 0.29) and USUP (range -0.27 to -0.33). Note that these are simple correlations and are not corrected for age of the cow. The correlations between calf WWT with calf PW ADG (range 0.71 to 0.81), calf BCS (range 0.20 to 0.37) and CW (range 0.25 to 0.29) were significant in all analyses ($P < 0.001$). The correlation of calf weaning weight was also significant with cow USUP in ET (-0.15, $P < 0.05$) and PHS (-0.12, $P < 0.001$) analyses.

Cow BCS was correlated ($P < 0.05$) with calf BCS in ET (0.15) and PHS (0.10) analyses but not in NS. Cow BCS was correlated ($P < 0.001$) with CW in all analyses (range 0.33 to 0.41). In regards to udder characteristics, cow BCS was correlated ($P < 0.05$) with AVTL in all analyses (range 0.12 to 0.13). Cow BCS was correlated with AVTD in ET (0.17, $P < 0.001$) and PHS (0.11, $P < 0.05$) analyses. The correlation coefficient between cow BCS and USUP in ET cows was -0.11 ($P < 0.05$). Cow weight was correlated with AVTL (range 0.27 to 0.29), AVTD (range 0.23 to 0.32), and USUP (range -0.17 to -0.25) in all analyses ($P < 0.05$).

Calf BCS was correlated with CW (range 0.15 to 0.39), AVTL (range 0.17 to 0.56), AVTD (range .16 to 40), and USUP (-0.24 to -0.32) in all analyses ($P < 0.05$). In all analyses the correlations between PW ADG with calf BCS (range 0.32 to 0.42) and CW (range 0.27 to 0.34) were significant ($P < 0.001$). Preweaning ADG was also correlated ($P < 0.001$) with AVTL (range 0.20 to 0.29), AVTD (range 0.23 to 0.27), and USUP (range -0.28 to -0.32) in the 3 analyses. Frisch (1982) found that as teat length and diameter increased that ADG of calves increased as well, due to more milk production of the cow. Although not significant, in the current study the correlations between WWT and AVTL (range 0.02 to 0.06) and AVTD (range 0.05 to 0.08) were positive.

Average teat length was negatively correlated with USUP (range -0.39 to -0.49) and moderately to highly positively correlated with AVTD (range 0.63 to 0.67) in all analyses ($P < 0.001$). Average teat diameter was moderately correlated with USUP (range -0.53 to -0.60) in all analyses ($P < 0.001$). Short et al. (1991) reported longer teats were associated with weaker udder support and deeper udders in Holstein cattle.

Disposition was not significantly correlated with any of the other traits. Funkhouser (2008) reported disposition in first calf heifers was correlated with weaning disposition (0.34, $P < 0.001$) and disposition in second calf females (0.53, $P < 0.001$).

In a separate analysis, cow age was evaluated for associations with weight- and udder-type traits. The correlation between cow age and BWT, WWT, PWADG, and CW in ET cows was 0.28, 0.32, 0.35, and 0.55, respectively. The corresponding correlations in NS cows were 0.42, 0.34, 0.45, and 0.40, respectively. The correlations between cow age and AVTL, AVTD, and USUP in ET cows were 0.39, 0.34, and -0.32, respectively. In NS cows these correlations were 0.46, 0.35, and -0.38, respectively. In general, as cows aged weight-type traits of cow and calf increased. Also, teat length and diameter increased while udders got looser in attachment.

CHAPTER V

SUMMARY

In this study, *Bos indicus – Bos taurus* cross cows were evaluated to determine sire of cow and family effects. Cows were produced from 13 embryo transfer (ET) full sibling families (F_2 Nellore-Angus) and 4 half sibling natural service (NS) families (dams were 1/2 Brahman 1/2 British cows) from the same 4 F_1 Nellore-Angus sires. Embryo transfer and NS cows were analyzed separately and together (PHS). Calving rate, weaning rate, cow disposition, average teat length, average teat diameter, udder support score, birth weight, weaning weight, preweaning average daily gain, cow body condition score, calf body condition score, and cow weight were evaluated in 2 to 6 yr old cows from the McGregor Genomics Project.

Effects modeled were sire of cow and age of cow nested within year of calf birth. Family nested within sire of cow was included for ET cows. Season of cow birth was included for ET and PHS cows. Cow nested within family was included as a random effect. Dam of cow nested within dam breed type was included as random effects in NS cows. Sex of calf was included in birth weight (BWT), weaning weight (WWT), preweaning average daily gain (PW ADG), and calf body condition score (BCS) analyses. Cow age was included in the model for disposition rather than cow age nested within calf year of birth. For cow weight (CW) and cow BCS, 2 level class variables were included for effect of a perfect calving record and lactation status. In addition, residuals were calculated on all cows in the three analyses for the 12 traits.

Daughters of sire 437J had the highest calving and weaning rate in all analyses. Daughters of bull 551G were the lowest in calving and weaning rate among ET cows and daughters of 297J were the lowest among NS cows. Within sire 551G, family 76 was numerically small and had a large effect on his least squares mean. Fall born cows tended to be higher for CR and WR than spring born cows. But it is important to note that fall born cows were allowed to calved as 2.5 yr olds in the spring (n = 60) with the exception of nine that calved as 2 yr old in the fall. As expected, the correlations between CR and WR were large (range 0.78 to 0.84) in all analyses. Calving rate was negatively correlated ($P < 0.001$) with cow BCS in all analyses (range -0.27 to -0.31) and with CW in ET and PHS (range -0.25 to -0.26). Weaning rate was also negatively correlated ($P < 0.001$) with cow BCS later that year (range -0.34 to -0.38) and CW (range -0.31 to -0.33) in all analyses. This suggests cows that did not give birth or wean a calf put on more flesh and weight than those that did.

In regards to DISP, sire of cow was significant in ET and PHS analyses but not in the NS cows. Daughters of bulls 437J and 551G were the highest (least docile) for disposition score in ET and PHS analyses. Daughters of bull 432H were the lowest (most docile) in all analyses. In NS, daughters of sires 297J and 551G tended to be higher (less docile) than daughters of 432H and 437J. Families 71 and 73 were the lowest and family 84 was the highest. It is important to note family 73 had 7 calves total out of two cows. In ET and PHS cows, 2 yr old cows were more docile than cows older than 4 yr. In NS cows, 2 yr old cows were more docile than 3 yr old cows.

Sire of cow was significant in all udder trait analyses except AVTD in ET cows. Daughters of bulls 297J and 551G had longer AVTL, larger AVTD, and lower (more pendulous) USUP scores in comparison to daughters of 432H and 437J. Family nested within sire of cow was important in AVTL for ET cows. As cow age increased, AVTL got longer, AVTD got larger, and USUP scores decreased. Average teat length was moderately to highly correlated with AVTD (range 0.63 to 0.67) and USUP (range -0.39 to -0.49) in all analyses ($P < 0.001$). Average teat diameter was moderately correlated with USUP (range -0.53 to -0.60) in all analyses ($P < 0.001$).

For BWT, calves out of daughters by bull 551G were the heaviest. Calves out of daughters of bulls 432H and 437J were the lightest at birth in NS and PHS analyses. As cow age increased, BWT tended to increase as well. Sex of calf was significant. Male calves were heavier at birth than female calves by 2.2 kg, 0.9 kg, and 1.8 kg in ET, NS, and PHS, respectively. Birth weight was correlated ($P < 0.001$) with WWT (range 0.33 to 0.38) and PW ADG (range 0.52 to 0.55) in all analyses. BWT was also correlated ($P < 0.001$) with calf BCS (range 0.24 to 0.25), CW (0.28), AVTL (range 0.21 to 0.32), AVTD (range 0.18 to 0.29) and USUP (range -0.27 to -0.33) in all analyses. Note that these are simple correlations, and they reflect the changes in these traits of both the cow and calf as the cow ages. The BWT analyses did not include calving day nested within year as a covariate. However, from a separate analysis, the regressions of BWT on calving day within year was 0.04 kg/d ($P = 0.02$), 0.05 kg/d ($P = 0.004$), and 0.04 kg/d ($P < 0.001$) for ET, NS, and PHS cows, respectively.

Sire of cow was significant in WWT of ET and PHS but not NS. Calves out of daughters by bull 297J were the heaviest at weaning in ET and PHS cows. Calves out of daughters of 432H were the lightest in all analyses. Calves out of cows in families 73 and 82 were the lightest. It is important to note that families 73 and 82 had 7 and 14 total born calves, respectively, and had a large effect on this bull's least squares mean. As cow age increased so did WWT. Calves out of fall born cows were heavier than those out of spring born cows. Note than all fall born cows were allowed to calve at 2.5 yr of age, and that the fall born cows were actually about 6 mo older than the spring born cows at any time, as designated in the analyses. Male calves were heavier than female calves at weaning by 11.0 kg for ET and PHS and 9.8 kg for NS cows. The correlations between WWT with PW ADG were high (range 0.71 to 0.81). The regression of WWT on weaning age of calf was 0.82 ± 0.07 kg/d in ET, 0.71 ± 0.08 kg/d in NS, and 0.78 ± 0.05 in PHS cows (all $P < 0.001$).

Sire of cow was also significant in PW ADG of calves from ET cows. Calves from daughters of bulls 297J and 437J gained the most weight, on average, from birth to weaning. Calves from daughters of 432H gained the least from birth to weaning, but as with WWT note the effects of the numerically small families 73 and 82 on the adjusted mean for this bull. Calves from 4 through 6 yr old cows gained more weight before weaning. Fall born cows raised calves that gained more weight than spring born cows. Again note the fall born cows were actually about 6 mo older than the spring born cows at any age, as designated in the analyses. Males calves had heavier PW ADG than females calves in ET (0.96 versus 0.91 kg/d), NS (0.97 versus 0.91 kg/d), and PHS (0.97 versus 0.91 kg/d).

Daughters of bull 437J had the highest body condition score (BCS) at weaning in all analyses while daughters of 551G were the lowest in ET and NS cows. Within sire 551G, family 76 is numerically small and had a large effect on this bull's least squares mean. Cows born in the fall were in heavier condition at weaning than those born in the spring. It is important to note that fall born cows were allowed to calve at 2.5 yr of age compared to the spring born cows that were 2 yr of age at calving. Cows that were not lactating as of July 1 were in heavier condition at the time of weaning of the other cows' calves by 0.60, 0.56, and 0.53 units of BCS in ET, NS, and PHS, respectively. Cow BCS was correlated with CW in all analyses (range 0.33 to 0.41), but note that these are simple correlations and reflect the increases in both characters as the cows increase in age.

Calves from daughters of 297J had the highest BCS at weaning in all analyses. In ET and PHS analyses, cows 4 yr of age and older tended to wean calves in heavier condition than younger cows. The same trend was seen in NS cows except in 2008 where 3 yr old cows weaned calves in heavier condition. Calves from fall born cows were in heavier condition at weaning than those from spring born cows. Male calves tended to be heavier conditioned at weaning than females. In ET cows, calf BCS was correlated with CW (0.39), AVTL (0.56), AVTD (0.40), and USUP (-0.32), as noted earlier these correlations are not corrected for the increases in the ages of the cows.

Daughters of bull 551G were the lightest in weight at the time of weaning of their calves in all analyses. Daughters of 437J were the heaviest in NS and PHS cows, and daughters of 432H were the heaviest in ET cows. Family nested within sire of cow was significant for CW. Fall born cows were heavier than spring born cows by 15.7 kg and 19.7 kg for ET (Table 20) and PHS (Table 22). This could be due to fall born cows allowed to calve at 2.5 yr of age compared to the spring born cows that were 2 yr of age at calving and were actually about 6 mo older than the spring born cows at any age, as designated in the analyses. Natural service cows that failed at least once to wean a calf (464.7 kg) were heavier than those that had a perfect calving record (450.6 kg). Cows that were not lactating as of July 1 were heavier at the time of weaning of the other cows' calves by 61.2, 64.6, and 64.3 kg for ET, NS, and PHS, respectively, than those that were lactating.

This research will be continued and used to measure lifetime cow productivity. There appears to be sufficient variability within and between these full sibling and half sibling families to allow for the identification of genes or chromosomal locations associated with the performance for many traits. The results of this research will be used to help identify genetic markers for cow productivity. These genetic markers, and ultimately the causative genes, could be used in the future as part of breeding strategies to aid producers in selection for important cow productivity traits in *Bos indicus – Bos taurus* cross cows.

LITERATURE CITED

Bailey, C. M., D. R. Hanks, W. D. Foote, and Y. O. Koh. 1988. Maternal characteristics of young dams representing *Bos taurus* and *Bos indicus* x *Bos taurus* breed types. J. Anim. Sci. 66: 1144-1152.

Breuer, K., P. H. Hemsworth, J. L. Barnett, L. R. Matthews, and G. J. Coleman. 2000. Behavioral response to humans and the productivity of commercial dairy cows. Appl. Anim. Behav. Sci. 66:273-288.

Burrow, H. M. 1997. Measurements of temperament and their relationships with performance traits of beef cattle. Anim. Breeding Abstr. 65: 477-495.

Burrow, H. M. and Corbet, N. J. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. Aust. J. Agric. Res. 51:155–162.

Cafe, L. M., D. L. Robinson, D. M. Ferguson, B. L. McIntyre, G. H. Geesink, and P. L. Greenwood. 2011. Cattle temperament: Persistence of assessments and associations with productivity, efficiency, carcass and meat quality traits. J. Anim. Sci. 89:1452-1465.

Cartwright, T. C. 1980. Prognosis of Zebu cattle: Research and application. J. Anim. Sci. 50: 1221-1226.

Cartwright, T. C., G. F. Ellis, W. E. Kruse, and E. K. Crouch. 1964. Hybrid vigor from Brahman-Hereford crosses. Texas Agric. Exp. Sta. Tech. Mono. 1. College Station, TX.

Cooper, A. J., J. O. Sanders, A. D. Herring, C. A. Gill, D. K. Lunt, and J. E. Sawyer. 2009. Evaluation of birth weight, weaning weight, and gestation length in *Bos indicus/Bos taurus* cross calves. Page 2. Abstract. Proc. Amer. Soc. Anim. Sci. Southern Section.

Cundiff, L. V. 2005. Performance of tropically adapted breeds in a temperate environment: Calving, growth, reproduction and maternal traits. Southern Cooperative Series Bulletin. 405: 131-143.

Cundiff, L. V., K. E. Gregory, T. L. Wheeler, S. D. Shackelford, M. Koohmaraie, H. C. Frettly, and D. D. Lunstra. 1995. Preliminary results from cycle V of the cattle germplasm evaluation program at the Roman L. Hruska U.S. Meat Animal Research Center. Progress Report 14. Roman L. Hruska U.S. Meat Animal Research Center, USDA. Clay Center, NE.

Edwards, S. A. 1982. Factors affecting the time to first suckling in dairy calves. Anim. Prod. 34: 339-346.

Fell, L. R., I. G. Colditz, K. H. Walker, and D. L. Watson. 1999. Associations between temperament, performance and immune function in cattle entering a commercial feedlot. Aust. J. Exp. Ag. 39:795-802.

Ferrell, C. L. and T. G. Jenkins, 1985. Cow type and the nutritional environment: Nutritional aspects. J. Anim. Sci. 61:725.

Fiss, C. F. and J. W. Wilton. 1992. Contribution of breed, cow weight, and milk yield to the traits of heifers and cows in four beef breeding systems. J. Anim. Sci. 70: 3686-3696.

Franke, D. E. 1980. Breed and heterosis effects of American Zebu cattle. J. Anim. Sci. 50:1206-1214.

Freeman, A. E. 1976. Management traits in dairy cattle, dystocia, udder characteristics related to production, and a review of other traits. Livest. Prod. Sci. 3:13–26.

Frisch, J. E. 1982. The use of teat-size measurements or calf weaning weight as an aid to selection against teat defects in cattle. Anim. Prod. 32: 127-133.

Fuerst-Waltl, B., J. Sölkner, A. Essl, I. Hoeschele, and C. Fuerst. 1998. Non-linearity in the genetic relationship between milk yield and type traits in Holstein cattle. Livest. Prod. Sci. 57: 41-47.

Funkhouser, R. R. 2008. Evaluation of disposition scores in *Bos indicus/Bos taurus* cross calves at different stages of production. M.S. Thesis, Texas A&M University, College Station.

Gladney, C. J. 2008. Evaluation of udder and teat characteristics, calf growth, and reproduction in young *Bos indicus – Bos taurus* cows. M.S. Thesis, Texas A&M University, College Station.

Grandin, T. 1993. Behavioral agitation during handling of cattle is persistent over time. Appl. Anim. Behav. Sci. 36:1-9.

Herd, D. B. and L. R. Sprott. 1986. Body condition, nutrition and reproduction of beef cows. Texas Agric. Ext. Bull. B-1526.

Hickman, C. G. 1964. Teat shape and size in relation to production characteristics and mastitis in dairy cattle. J. Dairy Sci. 47:777–782.

Jenkins, T. G. and C. L. Ferrell. 2004. Preweaning efficiency for mature cows of breed crosses from tropically adapted *Bos indicus* and *Bos taurus* and unadapted *Bos taurus* breeds. J. Anim. Sci. 82:1876-1881.

Kunkle, W. E., R. S. Sands and D. O. Rae. 1994. Effect of body condition on productivity in beef cattle. M. Fields and R. Sands (Ed.) Factors Affecting Calf Crop. Pp 167-178. CRC Press, Boca Raton, FL.

MacNeil, M. D. and T. B. Mott. 2006. Genetic analysis of gain from birth to weaning, milk production, and udder conformation in Line 1 Hereford cattle. J. Anim. Sci. 84: 1639-1645.

McCarter, M. N., D. S. Buchanan, and R. R. Frahm. 1991. Comparison of crossbred cows containing various proportions of Brahman in spring or fall calving systems: III. Productivity as three-, four-, and five-year olds. J. Anim. Sci. 69:2754-2761.

Melton, B. E. 1995. Conception to consumption: The economics of genetic improvement. In: Proc. Beef Improvement Federation, Sheridan, WY. pp 40-87.

Meyer, K., M. J. Carrick, and B. J. P. Donnelly. 1994. Genetic parameters for milk production of Australian beef cows and weaning weight of their calves. J. Anim. Sci. 72: 1155-1165.

Montaño-Bermudez, M. and M. K. Nielsen. 1990. Biological efficiency to weaning and to slaughter of crossbred beef cattle with different genetic potential for milk. J. Anim. Sci. 68: 2297-2309.

Moore, R. K., S. Higgins, B. W. Kennedy, and E. B. Burnside. 1981. Relationships of teat conformation and udder height to milk flow rate and milk production in Holsteins. Can. J. Anim. Sci. 61:493–501.

Morris, C. A., Cullen, N. G., Kilgour, R. & Bremner, K. J. 1994. Some genetic factors affecting temperament in *Bos taurus* cattle. N. Z. J. Agric. Res. 37:167–175.

Olson, L. W., D. E. Peschel, W. H. Paulson, and J. J. Rutledge. 1982. Effects of cow size on cow productivity and on calf growth, postweaning growth efficiency and carcass traits. J. Anim. Sci. 54: 704-712.

Paschal, J. C., J. O. Sanders, and J. L. Kerr. 1991. Calving and weaning characteristics of Angus-, Gray Brahman-, Gir-, Indu-Brazil-, Nellore-, and Red Brahman-sired F_1 calves. J. Anim. Sci. 69:2395-2402.

Prayaga, K. C. 2003. Evaluation of beef cattle genotypes and estimation of direct and maternal genetics effects in a tropical environment. 2. Adaptive and temperament traits. Aust. J. Agric. Res. 54:1027-1038.

Riley, D. G., C. C. Chase, Jr., T. A. Olson, S. W. Coleman, and A. C. Hammond. 2004. Genetic and nongenetic influences on vigor at birth and preweaning mortality of purebred and high percentage Brahman calves. J. Anim. Sci. 82: 1581-1588.

Riley, D. G., J. O. Sanders, R. E. Knutson, and D. K. Lunt. 2001a. Comparison of F_1 *Bos indicus* x Hereford cows in central Texas: I. Reproductive, maternal, and size traits. J. Anim. Sci. 79: 1431-1438.

Riley, D. G., J. O. Sanders, R. E. Knutson, and D. K. Lunt. 2001b. Comparison of F_1 *Bos indicus* x Hereford cows in central Texas: II. Udder, mouth, longevity, and lifetime productivity. J. Anim. Sci. 79: 1439-1449.

Roberson, R. L., J. O. Sanders, and T. C. Cartwright. 1986. Direct and maternal genetic effects on preweaning characters of Brahman, Hereford, and Brahman-Hereford crossbred cattle. J. Anim. Sci. 63:438-446.

Rogers, G. W. and G. L. Hargrove. 1993. Absence of quadratic relationships between genetic evaluations for somatic cell scores and udder linear traits. J. Dairy Sci. 76:3601–3606.

Rohrer, G.A., J.F. Baker, C.R. Long, and T.C. Cartwright. 1988. Productive longevity of first-cross cows produced in a five-breed diallel: I. Reasons for removal. J. Anim. Sci. 66: 2826-2835.

Sanders, J. O. 1980. History and development of Zebu cattle in the United States. J. Anim. Sci. 50:1188-1200.

Sanders, J., K. Key, D. Riley, and D. Lunt. 2005. Evaluation of heterosis retention for cow productivity traits in *Bos indicus*/*Bos taurus* crosses. Southern Cooperative Series Bulletin. 405: 212-220.

Sapp, R. L., R. Rekaya, and J. K. Bertrand. 2004. Teat scores in first-parity Gelbvieh cows: Relationship with suspensory score and calf growth traits. J. Anim. Sci. 82:2277-2284.

Selman, I. E., A. D. McEwan, and E. W. Fisher. 1970. Studies on natural suckling in cattle during the first eight hours post partum: II. Behavioral studies. Anim. Behav. 18: 284-289.

Seykora, A. J. and B. T. McDaniel. 1986. Genetics, statistics, and relationships of teat and udder traits, somatic cell counts, and milk production. J. Dairy Sci. 69:2395–2407.

Short, T. H., T. J. Lawlor, Jr., and K. L. Lee. 1991. Genetic parameters for three experimental linear type traits. J. Dairy Sci. 74:2020–2025.

Vargas, C. A., T. A. Olson, C. C. Chase, Jr., A. C. Hammond and M. A. Elzo. 1999. Influence of frame size and body condition score on performance of Brahman cattle. J. Anim. Sci. 77:3140-3149.

Ventorp, M. and P. Michanek. 1992. The importance of udder and teat conformation for teat seeking by the newborn calf. J. Dairy Sci. 75: 262-268.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612.

Wythe, L. D., Jr. 1970. Genetic and environmental effects on characters related to productive ability of the American Brahman. Ph.D. Diss., Texas A&M Univ., College Station.

VITA

Name: Aaron Jay Cooper

Address: Department of Animal Science
c/o James O. Sanders
432 Kleberg, 2471 TAMU,
College Station, TX, 77843-2471

Email Address: coopaaron@gmail.com

Education: B.S., Animal Science, Texas A&M University, 2005
M.S., Animal Breeding & Genetics, University of Nebraska, 2007
Ph.D., Animal Breeding, Texas A&M University, 2011